COMPUTER EDUCATION

Correction

Page 49, Appendix 6, *delete* note 2 and *substitute:*—

(2) 30 students on a two-year part-time diploma course reduced to 18 in second year. In 1966 the course was replaced by a M.Sc. course lasting either one year full-time or two years part-time.

Department of Education and Science
April 1967

LONDON: HER MAJESTY'S STATIONERY OFFICE

I. INTRODUCTION, NOMENCLATURE AND SUMMARY

TERMS OF REFERENCE

1. The background to our enquiry is the prospective rapid increase in the United Kingdom in the use of electronic digital computers of all kinds. The estimates put before us are that the total number of computers in use can be expected to rise from about 1,000 in 1965 to at least 3,000 in 1970, ranging from major installations in universities and elsewhere costing well over £1 million down to those costing £10,000 or so.

2. In these circumstances the Department of Education and Science, in consultation with the Ministry of Technology and other Government Departments concerned, decided in October 1965 to establish an interdepartmental working group with the following terms of reference:

> "To consider what steps can be usefully taken in the educational system to improve the supply of trained personnel working with computers, in the light of expected demand for such personnel".

MEMBERSHIP

3. The Working Group met under the chairmanship of the Department of Education and Science, and the following were represented—Department of Education and Science (Universities, General Science and Further Education Branches and H.M. Inspectorate); Scottish Education Department; Ministry of Education for Northern Ireland; Ministry of Technology; Ministry of Labour; Science Research Council; and University Grants Committee.

PROCEDURE

4. We have held 12 meetings. We have had the advantage of an assessment of shortages of computer staff compiled by the Ministry of Technology after discussions with leading computer manufacturers and consultants and endorsed in general by them in the Ministry's Consultative Group on Computer Staff. There have been discussions with the Consultative Group itself. We have also had the help of the Civil Service Commission, Government Communications Headquarters, and the British Computer Society. Our report relates to computer education throughout the United Kingdom.

INTRODUCTION

5. Underlying our remit has been the concern felt in many quarters that the number of personnel suited to work with and develop computer systems is not keeping pace with the rate at which computers can and are expected to be installed in industry, commerce and administration during the next few years. Vivid pictures, supported by estimates, have been produced of the damage to the development of the economy if this happens.

6. Our own enquiry has shown a very considerable demand for such personnel during the next few years, and to fulfil it effort will need to be co-ordinated, con-

centrated on critical points, and properly distributed between what should be done within the educational system and what should be done by industry. Because the skills associated with computer work are not yet familiar ideas to most people there may be a tendency to regard them as necessarily something which the educational system alone can provide. We do not consider this is a correct view. All industries have a training need which it is the function of the education service to supplement, not to fulfil; and this computer training requirement is as great in industry as in other cases—perhaps greater.

7. The distinction between the training and the educational elements is important to the approach we have adopted. Our concern is with what the educational system can achieve. We believe that colleges and universities should not be expected to do the training in specific narrow skills, which remains largely the responsibility of industry. But we recognise that educational institutions of many kinds can make a special contribution towards the development of computer staff; and consider that the role of these institutions is to provide, at different levels, an understanding of computer logic and languages, of computer systems, and of the ways in which a computer can rationalise an organisation's data processing arrangements.

8. If this country had had longer experience with computers, we might reasonably expect that all managers would have a reasonable familiarity with the way in which a computer can assist in the process of decision making. We have to recognise that the average manager's appreciation of the potential of computers is far from satisfactory; and we have a long way to go towards achieving clear cut definitions of the main categories of computer staff, and of the kind of people required.

9. The importance of computers is that they can transform the operations to which they are applied or perform operations which could not, in practice, be performed before. For this reason the demand of the computer is not only for people who understand and develop the machines ("hardware") and their associated programming facilities ("software"); but for people who understand the potentialities of machines in relation to particular situations and can effectively apply them. The first group are likely to be engineers and those with mathematical skills; the second are as much managers and organisers as computer experts. For both personality plays a large part, as well as education: but different personal qualities, as well as different training, are required for the two types of staff.

10. What we have said above shows the danger of an approach to the provision of personnel which fails to differentiate between the different kinds of people suited to work with computers. We do not, however, wish to underplay the importance of introducing a more generalised acquaintance with computers into the educational system, and we make recommendations on this. In particular, outside the range of people who might be described broadly as "computer staff", the more generalised executive and organiser will increasingly need a grounding in computer techniques. The responsibility for providing this will fall on business and professional education and training as a whole.

11. Though there are many problems to be faced, and the gap to be closed is considerable, we have been encouraged to find a strongly developing interest in computer education at all levels of the educational system, from the universities

to the schools; and a consciousness among the public that computers present new career opportunities. There is a wealth of, sometimes conflicting, initiative and enthusiasm. While there are some areas where stimulus is needed (these we have tried to identify), a very important need at this stage is for co-ordination of, and more information about, what courses for computer education are available.

NOMENCLATURE

12. In the present formative stage there are fine variations in grading of posts in the computer field and no consensus about the names of the different kinds of personnel required. Nor is there any clear pattern of educational qualifications for particular jobs. We recognise that there may well be considerable overlap in jobs, that individuals may perform more than one task and that the pattern will certainly change and develop in future. The Ministry of Technology is at present discussing standardised job descriptions (and associated educational and training requirements) with the leading computer manufacturers and consultants. We have had to define our terms for the purposes of this report, and by confining ourselves to users and excluding manufacturing and design staff concerned with hardware, we have found five main areas of activity. These areas call for very different attainments and types of person; and within each there is a considerable range of skill and responsibility.

13. First, there is a relatively small group, employed mainly by computer manufacturers and by consultants, who are concerned with the design and development of computer software. This will often include the origination of programming languages and the designing of compilers. These staff members need the attributes normally connoted by the ability to obtain an honours degree in mathematics. While people working at this level are sometimes described as computer system designers, in this report we adopt the more common designation of *advanced programmers*, though these people (and their jobs) are distinct from the programmers whom we mention below.

14. Next comes the group concerned with the application of the computer to the particular operations on which it is to work. This is the field of *systems analysis*. Although there is so far little agreement about the attributes required of the personnel working in this field, it is clear that, if the systems analyst is to be able to rationalise his organisation's data processing system to enable it to be computerised, they include a sound grounding in data processing, knowledge of the practical possibilities of a range of equipment, and, from his own employer's point of view, an appreciation of office practice and commercial procedures, and, often, of production planning and control. Combined with this there must be a good knowledge of his firm's organisation and requirements. This knowledge must be such as will carry conviction with top management. At the senior levels creative gifts and technical knowledge of a high order within the user organisation's field of interest are required, and throughout the systems analyst range imagination and clarity of thought are essential.

15. Educational "portraits" and precise professional terminology for the people working in this field are lacking. As a whole they are commonly described as *systems analysts*, and we use this term in our report recognising that it is a generic rather than an exact description. In particular it covers at its senior levels one group concerned with the overall development of computerisation pro-

grammes, which we distinguish as *systems designers*. These will be of the calibre of graduates of computer science degree courses or other honours graduates and professionally qualified people with specialised post-qualification training. In the rest of the systems analysis field the picture is much less clear. A good deal seems to depend on the knowledge and ability of those concerned and the level at which they may be required to work. A degree does not appear to be essential, though many organisations feel it necessary to look for people of graduate quality in making appointments as systems analysts.

16. Thirdly, there are staff who produce the sequences of detailed instructions, called programs, which implement the system proposed and control the operations performed by the computer. These people, whom we call *programmers*, work mainly in the organisation which uses the computer. As computers become more complex, more of the processes performed by programmers are absorbed within the computer itself. The routine parts of programming do not demand any particular academic qualification, and staff for this work are usually recruited by interview and aptitude test. Some programmers may be found suitable for filling higher grades of job.

17. Fourthly, a large number of operating staff are needed for a computer installation, including data preparation and handling.* Within this group is a smaller group of staff who operate the consoles and those who may assume the responsibility of computer room supervisors. As with programmers, aptitude for the job is a more important entry qualification than academic ability. This group we describe as *operators*.

18. Finally, there are the staff engaged on maintenance. Hitherto the educational standards required for this type of job have varied from professional engineer to technician. Few graduates are now employed on this work which is generally undertaken by people with practical experience in the electronics and electro-mechanical fields and academic qualifications at about the National Certificates levels. We describe these people as *maintenance staff*.

19. For convenience we summarise in the following table the broad categories of computer staff, their general functions and basic standards, which we have adopted for the purpose of our report.

TABLE 1

Categories of Computer Staff

Name	*Function*	*Standard*
Advanced programmer	To design software with computer manufacturer in the light of hardware available	Honours degree calibre
Systems designer	To apply system to a particular organisation	Honours degree calibre
Systems analyst		Degree/professional potential; maturity and experience in organisation
Programmer	To write instructions for computer	Intelligent numerate people with aptitude and special training
Operator	To operate computer	Special course
Maintenance staff	To maintain computer	Technician

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* The training of these staff raises the question of more general clerical education appropriate for them, which we do not deal with in this report.

20. In addition to these, experienced staff are needed to run courses both at the computer manufacturers and in educational establishments.

EXCLUSIONS

21. We recognise that this classification does not cover all people working with computers, but our main concern, as we have said in paragraph 5, has been the requirements facing industry, commerce and administration and the means by which the educational system can best help to serve them. We have not concerned ourselves with other important applications, as yet at an early stage, such as in medicine and traffic control. Neither have we concerned ourselves with the supply of senior staff engaged in the design and development of computer hardware; these staff will need a graduate qualification in electronic engineering and will be employed only by the computer manufacturers. Furthermore, we have not taken account of the specialised needs arising from the use of computers for the research purposes outlined in the Flowers Report* or in the on-line control of industrial processes. Moreover, except in relation to computer appreciation courses for managers, we have only to a limited extent concerned ourselves with the general need to introduce computer-orientated studies into courses for non-specialist personnel.

SUMMARY OF FINDINGS AND RECOMMENDATIONS

22. We summarise below our main findings and recommendations.

(i) Findings

(1) The educational system, with which we are here concerned, can make an important contribution to the development of computer staff. The distinction between what the educational system can provide, and the training in specific narrow skills which is largely the responsibility of industry, is an essential one even though in practice the line between education and training is not always easy to draw (paragraphs 6, 7).

(2) In the present formative stage of computer development, there is no consensus about the names of the different kinds of personnel required, the qualifications they need, or the jobs they do. For the purpose of our report, we have identified five groups of personnel using computers: advanced programmers, systems analysts (including, at the highest level, systems designers), programmers, operators, and maintenance staff (paragraphs 12–19).

Estimates of demand

(3) We take as our starting point that (disregarding specialised and educational installations) there were over 1,000 computers of varying sizes in the United Kingdom in 1965 and that by 1970 their number is likely to grow to over 3,000 in operation or on order, with an additional 1,000 at the planning stage for which some staff will be required (paragraphs 23–26).

(4) The introduction of a computer system calls for careful phasing of staff recruitment and training over a substantial period. The need for computer staff some time before a machine is installed underlines the urgency of increasing immediately the supply of qualified computer staff (paragraphs 27–33).

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* A Report of a Joint Working Group on Computers for Research. Cmnd. 2883, H.M.S.O., 6s. 6d.

(5) It is estimated that by 1970 industry and commerce will need an additional 200 advanced programmers, at least 500 systems designers, 11,000 systems analysts, 19,000 programmers and 16,000 operators, in addition to maintenance staff and teachers of computer subjects. It is, however, essential to distinguish this demand for manpower from the demand on the educational system (paragraph 34).

(6) The computer manufacturers expect to be able to meet their customers' main training requirements for programmers and operators, and also to recruit and train maintenance staff. This is not the case with the more highly qualified staff or with systems analysts in general, and these are therefore the fields where shortages are to be expected (paragraphs 34–42).

The pool of ability

(7) There are large areas of computer work for which no special academic qualification is necessarily expected of computer personnel. Here selection may be determined by other criteria, such as basic aptitude. We consider that further research into the validity of existing tests and into alternative methods of testing is justified (paragraphs 48, 49).

(8) Mathematical or logical ability occupies, and will continue to occupy, a special place in the field of computer education and employment. We are encouraged to find that the pool of persons exhibiting mathematical ability is widening (paragraphs 50–54).

The existing educational provision

(9) There are encouraging signs that within the educational system an element of computer study is being introduced into many courses and syllabuses and that a new range of courses to meet specialist requirements is being designed (paragraph 55).

(10) Secondary school mathematics courses increasingly provide an introduction to computer concepts. Some interesting experiments in the application of computers and in the wider contacts of schools with local industry have been initiated. These developments in schools are being reinforced by refresher courses to keep teachers in touch with the latest developments (paragraphs 56–61).

(11) A significant computer element has been introduced into many further education courses in mathematics, sciences, engineering and business studies at levels ranging from Ordinary National Certificates and Diplomas through Higher National Certificates and Diplomas to degrees awarded by the Council for National Academic Awards and post-graduate studies. Enrolments on these courses are increasing (paragraphs 62–75).

(12) In the universities, there has been a substantial increase in the output and number of courses in mathematics, sciences, management and business studies. Many of these include aspects of computer techniques (paragraph 76).

(13) Colleges of further education are already making substantial provision for specialist computer personnel, and others have courses under consideration. Courses already available include City and Guilds of London Institute courses 319 and 320 and those for a Bachelor of Science degree in computer science awarded by the Council for National Academic Awards. The provision of specially designed courses for systems analysts is being discussed with industry. A

variety of specialist short courses and "topping off" courses have been provided to meet particular demands (paragraphs 77–87).

(14) Several universities provide opportunities for relevant post-graduate studies. Many of the courses are below their maximum, or even optimum, size. Some university computing laboratories are finding it hard to fill academic and research staff vacancies and are exploring short term solutions (paragraphs 88-90).

(15) A number of private establishments offer training courses for a career in programming or systems analysis. Persons wishing to enter the computer field should also enquire about suitable courses either from a computer manufacturer or a local education authority before commitment to a private course (paragraph 91).

The steps needed

(16) There is very little time by 1970 to secure substantial new additions to the output of courses leading to degrees and others of similar length. Existing facilities will need to be more effectively used and there is spare capacity. We therefore urge better liaison between education and industry and improved information services (paragraphs 93, 94).

(17) While we foresee no major difficulty in recruiting or training sufficient programmers, operators or maintenance staff, the supply position for the more creative grades is far less satisfactory (paragraphs 96, 97).

(ii) **Recommendations**

(18) As there is likely to be a crucial shortage of systems analysts unless positive steps are taken to deal with this matter through the progressive development of an integrated programme of education and training, an expert group representative of education and user interests should be created to work out:

(*a*) further suitable programmes for industry-based, non-graduate, student systems analysts, combining in-service training with either a full-time or day release course of further education; and

(*b*) the release by industry of students in sufficient numbers to justify the setting up of such courses in a number of centres

(paragraphs 98–100).

(19) For systems designers, the major requirement is for the re-orientation of some existing courses and for the increased provision of post-graduate and post-experience courses. Industry should release employees on salary to take advantage of them (paragraph 101).

(20) The introduction of computer concepts into secondary school courses will necessitate the provision of desk calculators and other scientific and mathematical equipment on an increasing scale (paragraph 103).

(21) Although we do not envisage that the teaching of particular programming skills will become a function of schools, limited experiment with new mathematics syllabuses in schools and the use of travelling computers for schools should continue; and the results should be assessed in due course (paragraphs 104, 105).

(22) The organised access of schools to computer installations (especially at colleges of further education) should be systematically encouraged. Colleges of education should also establish such links (paragraphs 106, 108).

(23) Proper regard should be paid to the needs of schools when considering computer applications and in allocating college computer time, and the claim of schools on computers in colleges of further education should be recognised as part of the justification for new and extended installations where these are proposed. Though we do not suggest a specific order of priority some such planned development would be advantageous (paragraphs 107, 109).

(24) Business schools, appropriate university departments and leading technical colleges should consider the provision of short computer appreciation courses, preferably residential, aimed specifically at senior executives (paragraphs 112, 113).

(25) Urgent attention should be given by the responsible bodies to the need to review existing syllabuses for professional, executive and higher technician courses. Colleges should be encouraged to provide short courses for persons already holding specialist qualifications in fields affected by computer applications (paragraphs 114, 115).

(26) Increased provision of courses for specialist computer staff should be made by colleges of further education. The suitability of the City and Guilds of London Institute courses 319 and 320 warrants their continued support and extension to other colleges with the collaboration of industry. Colleges of further education should also play an important part in meeting the urgent need for more courses for systems analysts and designers (paragraphs 116, 117).

(27) The spread of computer knowledge in schools and the expansion of specialist computer courses in colleges of further education will require an increased provision of special short courses for existing teachers. Local education authorities should be prepared to second teachers to attend such courses. Particularly over the next few years the help of industry should be enlisted to remedy the present severe shortage of teachers in colleges of further education with the requisite experience of computer work by providing experienced computer staff for full or part-time teaching appointments (paragraphs 118, 119).

(28) Universities should be encouraged to allow a measure of their increasing computer power for teaching purposes, and to give priority in their forward planning to high level courses devised in collaboration with computer manufacturers and relevant to the needs of industry, commerce and administration for advanced programmers and systems designers (paragraphs 120–122).

(29) Some university post-graduate courses provide a basis which, if developed, could go far to meet the large estimated requirement for systems designers. But as increased provision for both post-graduate and post-experience students is urgently needed, it is hoped that universities will recognise the importance of such courses in their plans for the next quinquennium (paragraphs 123, 124).

(30) Many of the existing post-graduate and post-experience courses do not yet appear to attract the full number of students they could accommodate. The possibility of an expert survey under the auspices of the University Grants Committee of the position in universities in the light of the comparative lack of support for existing post-graduate and post-experience computer courses should be urgently considered. Such a survey would take into account the nature of the courses now offered and the types of courses best suited to the needs of industry,

commerce and administration; and should provide a basis for further practical development (paragraphs 125–127).

(31) The obstacles to the award of post-graduate studentships in computing subjects to non-science graduates should be explored and as far as possible eliminated (paragraphs 128–131).

(32) Every effort should be made to encourage the full participation of industry in drawing up syllabuses, supplying part-time lecturers, publicising courses, releasing key staff to attend them, offering financial support to the students and providing facilities for practical training of college-based students. The industrial training boards can play a vital part in such developments and we hope that they will actively encourage employers to release staff at all levels to attend courses of computer education (paragraphs 132–138).

(33) The British Computer Society has prepared a list of computer and associated courses. We think that a detailed list of this kind should be published annually by a central agency. In due course this might become a function of the National Computing Centre. Other forms of publicity should continue (paragraphs 139–142).

(34) The British Computer Society has also published a careers booklet, and proposes to supplement this with an annual review. We welcome this, as it is important that careers masters and youth employment officers should be put in a more effective position to advise on computer careers. Local education authorities should consider the desirability of supplementing the literature available to them by arranging short courses and conferences (paragraphs 143, 144).

II. ESTIMATES OF DEMAND

NUMBER OF COMPUTERS

23. Various attempts have been made to estimate the growth in the number of computers in this country. Some of the apparently different forecasts may result from differences in what is counted. Some counts have included solely those computers which are fully operational, while others have included, in addition, those delivered but not yet operational, those on order and those still at the planning stage. The need for personnel applies to all these groups, as we show below, and we have therefore adopted this more comprehensive basis of forecasting for this report.

24. The further one looks into the future the more difficult it becomes to predict the order book and therefore the numbers and occupations of associated staff. Moreover the balance of skills required of computer staff may also change with technical developments and with a more extensive use of the computer in the control of an organisation's operations. For these reasons we have adopted 1970 as our point of reference, though we have taken into account the fact that expansion will continue beyond that date.

25. The Ministry of Labour Manpower Research Unit undertook a survey, which began in 1964, into the effects of computers on office employment* in the course of which it collected information about the numbers of computers. The Unit found that the number of computers of all types delivered for office work at

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* Ministry of Labour Manpower Studies No. 4: Computers in Offices, H.M.S.O., 1965, 4s.

the beginning of 1965 was 605. It estimated that by the beginning of 1970 2,650 computers or computer systems will have been installed. The figure did not take into account the computers which would then be on order or replacements for obsolete machines in all stages of development. Nor did it include the number of computers installed in educational and research establishments or those being used for industrial process control. The Ministry's enquiry did not extend to Northern Ireland, but a similar enquiry conducted in Northern Ireland by a committee appointed by the Minister of Commerce showed that in December 1965 11 computers were in use in commercial establishments in the Province.

26. The Ministry of Technology has told us that it estimated in 1965 that there were then over 1,000 computers in this country in all and that, by 1970, this figure was likely to have increased to some 3,000 or more. These estimates do not seem to be incompatible with those of the Ministry of Labour and for our purposes we have taken it that in 1970 there will be at least 3,000 computers either in operation or on order. We assume also that there will be another 1,000 at the planning stage for which some staff will be required. There will be, of course, a very great difference in size and complexity between the largest of these 4,000 machines and the smallest.

PHASING THE INTRODUCTION OF A COMPUTER SYSTEM

27. Before computer equipment is ordered a detailed analysis has to be undertaken of the work to be processed, the advantages of doing it by automatic data processing methods, and the capabilities of different computer systems and equipment (e.g. size of computer store, speed of operation, number and speed of magnetic tape units and specification of printers). This period, which calls for a complement of systems designers and analysts, may last for six months or more. At some point during this period some programmers may also be needed.

28. It is usually important that the systems analysis team and, where practicable, programming support should be at good strength as near as possible to the time the order for equipment is placed. Between placing the order and installing the machine there is a period lasting about twelve months during which there is often intense pressure to write programs in order to bring the expensive equipment into operation as soon as possible after it is received.

29. Qualified personnel are thus required some time before the machine is installed. Machines which are to be installed in 1970 will require a team of analysts and some programmers in post by 1968/69 or even sooner. These facts underline the urgency of taking immediate steps to increase the supply of qualified computer staff with which we deal in this report.

30. With delivery of the equipment it will be necessary to deploy a full team of analysts and programmers until the system is substantially loaded, which at present may take on average between a year and eighteen months. During this period the computer system is tested, normally in parallel with the existing system, and there is a gradual build-up in the volume and type of work processed.

31. After this phase the system can often be operated with fewer analysts and programmers, so that the number of computer staff employed on a particular block of work can generally be somewhat reduced. But the total computer staff

employed by an organisation may not fall. Additional uses may be found for the computer. With the more senior systems designers and analysts, there should be an appreciable "stage army" effect as computer projects mature and staff move on to fresh projects usually for the same organisation.

32. Keeping the installation and the programs up to date also requires staff at all levels. There is a surprising amount of this work, for more changes take place than are generally realised, and even small alterations to procedure can cause a large amount of reprogramming.

33. In time it becomes necessary to replace the computer with a new one. This calls for additional analysts and programmers, since the old and new systems normally have to overlap. At this stage, it is generally necessary to redesign the system and write new programs if full advantage is to be taken of a later machine which is capable of additional uses. The setting up of the replacement computer frequently takes as long as the original project, and this is likely to remain so for many years, at least until computers become standardised and automatic languages more acceptable.

CRITICAL STAFF SHORTAGES

34. According to the Ministry of Labour's survey in 1964 there were some 3,600 systems designers and analysts and 4,800 programmers. By 1970, they estimate that the numbers expected to be needed in these categories will have risen to 15,000 and 24,000 respectively. But it is essential to distinguish between demand for manpower and demand on the educational system. From discussions which the Ministry of Technology has had with computer manufacturers and consultants it seems that the computer manufacturers expect to be able to meet their customers' main training requirements for programmers and operators. This is not the case with the more highly qualified staff or with systems analysts in general, and these are therefore the fields where the most likely shortages can be expected. In the following paragraphs we discuss the demand as we see it for each of the main categories of staff in the order in which they are described in the previous chapter.

ADVANCED PROGRAMMERS

35. For the relatively small but important category of *advanced programmer*, the demand over the period to 1970 is expected to amount to a further 200 or so. They present a relatively smaller supply problem than systems designers and to a certain extent they tend to be "home-grown" by either the computer manufacturers or universities for their own installations.

SYSTEMS DESIGNERS AND SYSTEMS ANALYSTS

36. Although, as we have said in Chapter I, there is no agreement on the precise terminology or educational requirements for *systems analysts*, the general view in the computer industry is that this is already an area of shortage which could become critical unless appropriate steps are taken to deal with it.

37. Within this field, the need for *systems designers*, sometimes called advanced systems analysts, is especially acute. While many will enter this work as in the past by other routes, increasing numbers will come from the ranks of honours graduates with relevant post-graduate and post-experience training. Some well-

informed estimates put the additional systems designers ideally needed by 1970 from the higher educational system at not far short of 1,000. It is clear that anything short of 500 from all sources would seriously hamper the more extensive and economic application of computers to business operations.

38. While there is a special need for systems designers, the largest demand from most computer users in industry, commerce and administration is for *systems analysts* in general. We understand that it is virtually impossible for employers to find enough analysts, at any level; and estimate that about 11,000 more will be needed by 1970. There are indications that even today the efficiency of computers already in use is not fully taken up owing to the shortage of adequate systems analysts and that there is intense competition for those who have shown they can work effectively in this field. We therefore give special attention in Chapter V to this area of shortage.

PROGRAMMERS

39. In the case of programmers, the computer manufacturers are expecting to continue to meet both their own needs and their customers' requirements for courses in programming their particular machines; while colleges do not expect much difficulty in meeting demands for broader educational courses suitable for programmers, such as the City and Guilds of London Institute courses 319 and 320. The computer user needs to bring in one or two experienced programmers and for the rest to select people from his own staff to be given short courses by the computer manufacturers lasting up to five weeks. After six or nine months' experience on the job under competent supervision they can be regarded as reasonably effective programmers. Recruits do not seem to be difficult to find where there is already a large office staff (as in banks and insurance companies). It is not so easy in, say, a medium sized manufacturing company with a relatively small office staff.

40. In 1964 the computer manufacturers trained some 4,000 new programmers; they expect to train 6,000 in 1966, and see no great difficulty in increasing that number. Thus there seems every likelihood that, even allowing for their own requirements and for wastage, they will be able to meet the estimated need for an extra 19,000 programmers by 1970.

OPERATORS

41. We doubt whether the training of computer operators will be a special educational problem. The Ministry of Labour's survey gave the number of computer operators employed in 1964 as nearly 3,000 and estimated that this number will rise to 19,000 by 1970. There is little evidence of current problems in recruiting enough operators, most of whom seem to be drawn from within the user organisations. Training is mainly provided by the computer manufacturers. The basic course is short—one to two weeks—and is followed by training on the job under supervision. In some installations, small ones in particular, operators pick up the work from the computer manufacturers' representatives on the spot, without undergoing formal courses away from the job.

MAINTENANCE STAFF

42. Few estimates have been made of industrial requirements for maintenance staff. From enquiries made by the Ministry of Technology it seems that there

were between 2,500 and 3,000 employed in 1965. These men are primarily engineering technicians recruited largely from industry and trained in the computers manufacturers' own training schools. Practical work on a broad range of computers is an important element of training and in general computer manufacturers expect to be able to recruit and train sufficient people for their needs for the next few years. After that the possibility of further advanced technological developments in computer manufacture has made it difficult to forecast with any reasonable certainty the demands for maintenance staff, either in terms of numbers or experience, but again their training does not appear to present any great difficulties.

TEACHERS

43. There will also be a need for experienced staff to be released to run courses. Where computer manufacturers provide training in a particular skill, it seems reasonable to expect them to supply the trainers. But where the educational system is responsible for providing computer courses, the need for an adequate supply of teachers must be borne in mind.

CONCLUSION

44. The demand for trained computer staff will roughly quadruple in the next four years—an increase of about 50 per cent per year. A great part of this demand for manpower, however, is not direct demand on the educational system. Three separate needs for fulfilling it have to be distinguished:

(*a*) Training within industry;

(*b*) Educational courses for computer personnel; and

(*c*) More generalised education designed for a computer world.

45. In the years immediately ahead shortages are more likely to develop in the field of systems design and analysis and to a lesser extent in advanced programming; it is here that the further and higher educational system can help most directly. There will, in addition, undoubtedly be a need for computing courses as part of the education and training requirements for a wide range of professions and occupations beyond those directly concerned with the operation of computer systems, or as a basis on which training can be successfully superimposed.

III. THE POOL OF ABILITY

46. Before examining the provision already made by the educational system for the education and training of computer staff, we look briefly at the size of the pool of ability suited to computer work, since this is an important factor in any assessment of the capacity of the educational system to meet the growing industrial demands for trained computer personnel.

47. Leaving aside for the moment the problem of mathematics, which raises special issues, a question which is often asked is whether other educational disciplines can provide specially suitable bases for computer work. It is sometimes suggested, for instance, that proficiency in classical languages, sciences, economics or logic, may be correlated with the aptitudes we seek, although we have no convincing evidence that this is so. The discipline imposed by any of these studies may nevertheless well be relevant.

48. There are very large areas of computer application—for example, in banking, insurance, and in central and local government—where no special qualification is necessarily expected of computer personnel. For this kind of work the selection of computer staff may be based on quite different criteria, such as knowledge of the work to be computerised, experience in organisation and methods, or performance in special aptitude tests.

49. We have consulted the Civil Service Commission, and others with experience of aptitude testing for programmers. The computer manufacturers find their own tests valuable, but finality has clearly not been reached in this field. The National Institute of Industrial Psychology, in co-operation with one of the computer manufacturers, is engaged in a research project covering the selection of computer programmers. We welcome this as we consider that further research into the validity of the existing tests and into alternative methods of testing is needed.

50. There are areas of computer use where specific mathematical attainment is essential. In many industrial concerns a knowledge of advanced mathematical techniques in the fields of operational research or statistical theory may be required of senior computer staff, and this is also true of large commercial or administrative organisations who are applying, or are considering applying, such techniques to their problems.

51. The application of mathematical techniques in business and administration is likely to expand considerably in future. This will mean not only a greater employment of specialist mathematicians, statisticians, and operational research experts in these fields; it will mean also that management and the more senior analysts and programmers will increasingly require to have at least an appreciation of these techniques.

52. These trends can be expected to continue. We are therefore sure that the aptitudes displayed by good performance in mathematics occupies, and will continue to occupy, a special place in the field with which we are concerned. Mathematics provides a suitable vehicle, though not the only one, for the introduction of computer concepts into schools; and familiarity with mathematical expressions helps in explaining and understanding the logic and notation of computer programs.

53. We have accordingly looked at the recent output of mathematical ability from the educational system in detail. Appendix 1 gives a summary of the growth in numbers of those who have secured mathematical qualifications at educational institutions. In the last five years the number of degrees, passes in the General Certificate of Education at Advanced level and passes at Ordinary level in mathematics have all increased by more than half. The pool from which will be recruited computer staff requiring mathematical qualifications and aptitudes is therefore widening. At the same time there will be increasing competition from other fields, especially education, for persons with such qualifications.

54. Fortunately, and this is a point we would emphasise, for the vast majority of computer staff at nearly all levels of employment some arithmetical or logical ability will be sufficient for practical purposes and they will not need to have carried the academic study of mathematics to any high level. The educational base for computer work will therefore be a wide one, with room for persons of

varying educational levels and specialisms, since suitability for such work is as much a matter of aptitude and application. It will also need to be reinforced by training. In the next chapter we examine the facilities provided in educational establishments to maintain and expand this base, and consider how far they serve the needs of industry, commerce and administration whose demands we discussed in Chapter II.

IV. THE EXISTING EDUCATIONAL PROVISION

55. There are encouraging indications that those responsible in the educational system—the schools, colleges, universities, professional bodies and others concerned in devising courses and keeping syllabuses up to date—are already introducing an appropriate element of computer study into many of their courses and syllabuses and are designing a new range of courses to meet specialist requirements. In this chapter we examine these developments in greater detail. First, we look at developments in school; then at generalised courses containing a significant computer element; and finally at specialist courses intended primarily for those working with computers.

AN INTRODUCTION TO COMPUTER CONCEPTS IN SCHOOLS

56. In the schools an introduction to the general principles of computer logic and notation is often provided as part of a secondary school mathematical course. It is generally agreed that school mathematics should in part be computer-orientated and that pupils, not only on the science side, should be acquainted with the uses and potentialities of computers. The teaching of binary arithmetic is now very common in the lower forms of secondary schools: flow charting is also in many syllabuses and becoming popular for the age range 11 to 16, while in sixth forms flow charting is further developed in connection with simple programming on desk calculators.

57. Of the several groups of schools which are at present working out new mathematics syllabuses, at least two, namely the Schools Mathematics Project and the Mathematics in Education and Industry Project, are including flow charting in their General Certificate of Education Advanced level syllabuses. A few schools do some work on truth-tables, Boolean algebra and switching circuits. Many schools arrange visits to neighbouring computer installations.

58. In reinforcement of these developments in schools, refresher courses for teachers are playing an important part. The Department of Education and Science and the Ministry of Education for Northern Ireland have arranged one-year courses of further training, mainly for non-graduate teachers. Up to 1960 (1949 in Northern Ireland) these teachers had only a two-year course of initial training. In addition, the Department arranges one-term courses in mathematics to teach the modern approach to this subject for younger pupils. One-term conversion courses in mathematics for arts graduates were held for three years from 1962, but unfortunately the demand was insufficient to justify continuation of the scheme. For all these courses teachers received their full salary. Various shorter courses, usually held during vacations, are also run by the Department, the Ministry of Education for Northern Ireland, the universities and others,

to keep teachers in touch with the latest developments, and the need for these will continue, though the major provision of courses will remain a local responsibility.

59. We have heard of only one school which has installed a new computer, which is being used for a new General Certificate of Education Advanced level syllabus in pure mathematics, including numerical methods and computing. At least one other school has been given a second-hand computer. One or two authorities are experimenting with travelling computers to serve a number of schools. These are interesting developments, though it is too early to assess their effect. The important aim is that pupils at school should become familiar with the possibilities of computers, rather than that they should learn specific computer skills. In our next chapter, therefore, we consider the desirability of such experiments, and comment on some of the ways in which we visualise the development of computer education at school level.

60. In Scotland, the introduction of alternative Ordinary grade mathematics syllabuses for examinations in 1968 has provided an opportunity for injecting modern ideas and topics into the teaching of mathematics in schools. The syllabuses contain a number of topics relevant to computer education. Some schools are constructing simple binary adding machines. It is expected that the course will include some mention of the working of a computer and that schools will be encouraged to arrange class visits to organisations possessing a computer. Several schools are exploring the possibilities of wider contacts with local industries and organisations using computers, while a number have arranged programming courses for their sixth form pupils given by technical college staffs. Revised syllabuses for the Higher grade and additional mathematics examinations are being planned to take account of these developments in schools; the revised additional mathematics syllabus will also have regard for the general impact of computers on society.

61. The momentum of these developments in schools depends on the teaching staffs themselves receiving a good grounding in the potentialities of a computer and some familiarisation with the processes involved. The colleges of cducation are becoming increasingly aware of the importance of introducing some appreciation of the role of computers and a knowledge of computer techniques into syllabuses, particularly for mathematics teachers.

GENERAL COURSES WITH SIGNIFICANT COMPUTER ELEMENT

(i) Colleges of Further Education

62. A particularly wide range of courses slanted towards industry and commerce is provided by colleges of further education. By 31st July, 1966, some 44 colleges, which we list in Appendix 2, had computer installations and others are under consideration. In the computer field, the courses they provide may be said to extend from Ordinary National Certificates (part-time) and Diplomas (full-time or sandwich) through Higher National Certificates and Diplomas to degrees awarded by the Council for National Academic Awards, and post-graduate studies. Many of these do not in themselves equip the student for specialist computer work, but some students who attend only a generalised course may later have a "topping off" course in industry or further education and thus qualify for higher level computer work.

63. At the level of the Ordinary National Certificate and Diploma, courses in sciences, engineering and business studies all play an effective part. Syllabuses and approaches are being rethought and the signs are promising.

64. In sciences, the reconstituted schemes usually contain elements of statistics and probability and an introduction to desk machine work and flow programming. This enables further studies at higher levels to be undertaken on a sound basis. The scheme, which came into operation in September 1965, also allows some students to specialise in mathematics; this is a new departure which will partly provide the intake into the new Higher National Certificate in mathematics, statistics and computing. It is expected that in engineering courses the mathematics syllabuses will be on similar lines.

65. The corresponding schemes in business studies have traditionally been non-mathematical; but, with the tendency to introduce the study of operational research, quantitative methods and possibly computer work at later Higher National stages, it is likely that an appropriate mathematics/statistics subject will soon be introduced as a strongly recommended option at the Ordinary National level. This will probably include linear algebra, statistics and probability, desk machine work and flow programming.

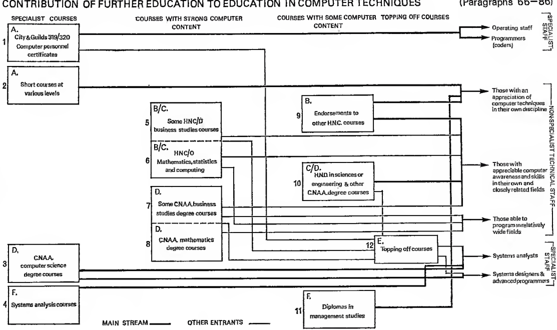
66. At the more advanced levels, the pattern is rather less clear cut. The variety of opportunity can best be brought out in diagrammatic form. The following chart shows the wide range of advanced courses in computer techniques, many of them above the level of Ordinary National Certificates and Diplomas and equivalent levels of school leavers, which are now provided in technical colleges in England, Wales and Northern Ireland, and the level of computer work which, after suitable topping off, students from the various courses may be expected to undertake.

67. At the Higher National level, as at the Ordinary National level, courses in sciences, engineering and business studies all make contributions towards computer education (see boxes 10 and 5 on the chart). In the majority of the Higher National Diploma courses in sciences or engineering, the mathematical teaching is computer-orientated, whilst in business studies a few recent Higher National Diploma schemes have deliberately set out to produce students with experience of data processing.

68. Rules for a new Higher National Certificate and Diploma scheme in mathematics, statistics and computing (box 6) were published in March 1966. The Higher National Certificate, and the proposed graduateship courses of the Institute of Mathematics and its Applications, will replace the Mathematical Association's Diploma in Mathematics (Technology), and the Higher National Diploma will take in the college diploma schemes currently running. These courses are, in some cases, lower level computer science courses, and all will contain a large element of computing. Initially about seven courses will be Higher National Diplomas including the three-year sandwich diploma courses in computer science at the John Dalton College of Technology, Manchester, and probably at Wolverhampton College of Technology. Wolverhampton had 18 students in 1964 and 14 in 1965; the John Dalton College started with 19 students in 1965. An additional throughput of some 300 Higher National Certificate students at first is forecast, based on current Diploma in Mathematics

CONTRIBUTION OF FURTHER EDUCATION TO EDUCATION IN COMPUTER TECHNIQUES

(Paragraphs 66—86)


SPECIALIST COURSES
COURSES WITH STRONG COMPUTER CONTENT
COURSES WITH SOME COMPUTER CONTENT
TOPPING OFF COURSES
1 A. City & Guilds 319/320 Computer personnel certificates
2 A. Short courses at various levels
3 D. C.N.A.A. computer science degree courses
4 F. Systems analysis courses
5 B/C. Some HNC/D business studies courses
6 B/C. HNC/D Mathematics, statistics and computing
7 D. Some C.N.A.A. business studies degree courses
8 D. C.N.A.A. mathematics degree courses
9 B. Endorsements to other H.N.C. courses
10 C/D. H.N.D. in sciences or engineering & other C.N.A.A. degree courses
11 F. Diplomas in management studies
12 E. Topping off courses
Operating staff
Programmers (coders)
SPECIALIST STAFF
Those with an appreciation of computer techniques in their own discipline
Those with appreciable computer awareness and skills in their own and closely related fields
Those able to program in relatively wide fields
NON-SPECIALIST TECHNICAL STAFF
Systems analysts
Systems designers & advanced programmers
SPECIALIST STAFF
MAIN STREAM
OTHER ENTRANTS

Notes on the Chart relating to the Contribution of Further Education to Education in Computer Techniques

1. The chart is designed to show the wide range of advanced courses in computer techniques provided in technical colleges in England, Wales and Northern Ireland for persons with different educational backgrounds and the level of computer work which, after suitable topping off, students from the various courses may be expected to undertake.

2. The numbers beside each box provide a means of identifying courses referred to in the text of the report.

3. The letters in the corner of each box indicate the minimum educational base required by students on each course, as follows:

A. Five years' secondary education; no minimum academic entry requirement.

B. Ordinary National Certificate or Diploma normally (school entry to Ordinary National Certificate or Diploma course requires four suitable General Certificate of Education Ordinary level passes).

C. General Certificate of Education, one Advanced level plus three Ordinary level passes OR Ordinary National Certificate or Diploma.

D. General Certificate of Education, two Advanced level plus three Ordinary level passes OR good Ordinary National Certificate or Diploma.

E. A course in box 1, 5, 6, 7, 8 or 10 plus experience of computer work.

F. Normally graduate or professional status and/or experience.

enrolments. Conversion courses for current students became available from September 1966.

69. Except in this new mathematics, statistics and computing Higher National Certificate syllabus, part-time courses do not normally include time for computer work. However it is worth noting that there is a growing tendency to offer an endorsement subject related to computing, particularly in engineering and sciences. Such an endorsement subject requires at least 80 hours' study, and so is a significant contribution, as shown on the chart (box 9).

70. There have been encouraging developments at both Ordinary and Higher National Certificate level in Scotland. The Ordinary and Higher National Certificate in mathematics, introduced in 1963/64, contains considerable elements of statistics and numerical analysis as well as modern mathematics, and makes use of computer-based material, especially at H.2 stage. The course is in operation in three colleges and available in one other, with over 110 students in various stages of the course.

71. In other National Certificate courses in Scotland mathematics has remained largely traditional in content and approach, but recent years have seen an introduction of elementary statistics and some work in numerical methods, especially, for example, in applied physics, building, chemistry and production engineering. The use of desk calculators in class work has been encouraged, and sometimes required, though not as yet in examinations. All mathematics syllabuses in Scottish National Certificate courses are now being reviewed in the light of the development of alternative syllabuses for school examinations referred to in paragraph 60 above. In the sphere of business studies, two new subjects, computer studies I and II, each requiring about 80 hours' study, have been added to the optional subjects of the Scottish National Certificate and the Scottish Advanced National Certificate in Business Studies respectively, while syllabuses of existing subjects of these certificates, such as statistics, office organisation and methods, and accounting, are being revised to take account of computer developments.

72. In Northern Ireland, the College of Technology, Belfast, has included computer applications in management studies courses as well as in special courses on numerical analysis and statistics. An introduction to computer programming and appreciation of the use of computers are included in the syllabuses of a variety of courses. One or two day intensive courses on special applications of computers to various fields of study, for example to structural engineering, have been arranged. The College has also conducted courses for sixth form pupils. Courses for the new Higher National Certificate and Diploma in mathematics, statistics and computing became available from 1966.

73. Moving to the more advanced levels, degree courses with a strong computing element are also available in colleges of further education, under the aegis of the Council for National Academic Awards. Courses for the Council's Bachelor of Science degree in mathematics (box 8 on the chart) require the study of mathematical disciplines with a marked slant towards industrial uses, either in business or in sciences and engineering. The qualification could lead into computer work with very little additional training. The following colleges at present offer four-year sandwich courses for this degree.

TABLE 2

Enrolments for C.N.A.A. Degree Courses in Mathematics

College	*Enrolments*		
	1964	*1965*	*1966*
(*a*) Courses with a scientific or engineering background			
Coventry, Lanchester College of Technology	10	12	10
Hatfield College of Technology	14	8	10
Newcastle, Rutherford College of Technology	7	9	11
Woolwich Polytechnic	18	7	18
	49	36	49
(*b*) Courses with a business background			
Enfield College of Technology	8	17	30
Leicester College of Technology	—	—	6
Portsmouth College of Technology	—	16	19
	8	33	55
Total	57	69	104

74. Proposals for degree courses in business studies (box 7) are being examined by the Council for National Academic Awards. Some of these will include a strong element of computing and data processing. Furthermore, the mathematics teaching associated with a majority of the Council's degree courses in science or engineering (box 10) is also computer-orientated.

75. Mention should also be made of the post-graduate Diplomas in Management Studies (shown in box 11 on the chart). These contain appreciation of computers, and so represent some effort to influence future top management. The courses also include appreciation of quantitative methods, including operational research.

(ii) Universities

76. As we have seen in Chapter III and Appendix 1, there has been a substantial increase in the output of mathematics graduates. In addition, there are a large number of other courses which take advantage of computer techniques. The Flowers Report on Computers for Research* said in paragraph 26 that "not a few university departments, especially in engineering, have already recognised computation as a necessary part of an undergraduate course, comparable in importance for the engineer to the use of machine tools or the drawing board". At least one university now expects that all science-based students will be given courses in numerical analysis, including machine programming. Moreover, some aspects of computer techniques are being included in management and business studies; for example, at the London Graduate School of Business Studies the second year of the post-graduate Master of Science curriculum will include two courses on operational research, including the use of electronic computers and knowledge of a simple programming language. The universities all either possess computers already, as shown in Appendix 3, or have installations under consideration. Many have added second installations, or have replaced their original ones by more powerful machines.

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* A report of a Joint Working Group on Computers for Research. Cmnd. 2883, H.M.S.O., 6s. 6d.

(i) Colleges of Further Education

77. Colleges of further education have assumed a substantial responsibility to provide suitable educational courses for computer staff, at all levels. These courses, too, are shown on the chart mentioned in paragraph 66.

78. 32 colleges, listed in Appendix 4, have introduced courses based on the City and Guilds of London Institute schemes 319 and 320 (box 1 on the chart). Course 319, leading to the Certificate for Computer Personnel, is based upon an appreciation of the uses and potentialities of computers, and is intended to provide a study of the basic techniques of programming, coding and operation, together with a knowledge of the relevant mathematics and statistics. It assumes that students will attend two-year (or in some cases three-year) part-time courses on day release or the equivalent (e.g. by block release). The first examinations for this certificate were held in the summer of 1966 when there were 62 entrants from the eight colleges shown in Appendix 4. About 20 more colleges offered the course in September 1966.

79. Course 320 for the Advanced Certificate for Computer Personnel is a part-time or block release course intended to provide a more advanced study of computer techniques, especially programming. Regulations have been issued and the course was offered by colleges for the first time in the autumn of 1966.

80. Apart from a few college diploma courses, courses at National Certificate and Diploma levels are not aimed specifically at those engaged on computer work, though it will be evident from paragraph 68 above that the new Higher National Certificate and Diploma in mathematics, statistics and computing (box 6) should go far to meet the demand for non-specialist technical staff with appreciable computer awareness and skills in their own and closely related fields.

81. The Council for National Academic Awards has accepted degree courses for specialist computer personnel. Courses for the Council's Bachelor of Science degree in computer science (box 3 on the chart) are offered at the six colleges shown in Table 3, and are rapidly expanding: in addition, Staffordshire College of Technology has in mind a one-year post-graduate course under the Council's aegis.

TABLE 3

Enrolments for C.N.A.A. Degree Courses in Computer Science

College of Technology	*Course*	*Enrolments*			*Notes*
		1964	*1965*	*1966*	
Brighton . .	3 year full-time	14	26	—	Students transferred to 4 year sandwich
Brighton . .	4 year sandwich	—	21	39	I.B.M. and I.C.T. sponsor students
Hatfield . .	4 year sandwich	—	14	52	
Leicester . .	4 year sandwich	—	—	9	
Middlesbrough (Constantine)	4 year sandwich	—	—	23	
Stafford . .	4 year sandwich	—	11	60	English Electric — Leo Marconi sponsor students
Wolverhampton .	4 year sandwich	—	32	32	
	Total	14	104	215	

82. Details of the Brighton and Hatfield four-year sandwich courses are given in Appendix 5. The Appendix also includes comparable details of the Higher National Diploma course at the John Dalton College of Technology, Manchester, mentioned in paragraph 68 above.

83. Eight or nine technical colleges, after consultation with computer manufacturers and user organisations, have already considered the provision of specially designed courses for systems analysts (box 4 on the chart). The consensus of industrial opinion seems to favour courses with a business rather than a scientific or engineering background. The syllabus may well include a theoretical introduction and elementary practice; feasibility studies and exercises; and practical experience on tackling a live problem, thus necessitating full co-operation between the college and computer manufacturer. This kind of course seems to be particularly suitable for organisation on a sandwich basis, involving alternate periods in college and industry, and we therefore consider it in more detail in paragraph 99 below.

84. In Scotland, the Scottish Council for Commercial, Administrative and Professional Education (S.C.C.A.P.E.) has decided, on the recommendation of a working party representative of educational and user interests, to offer a diploma in systems analysis and design. The course will be a full-time one of four to six months' duration, plus a period of required industrial experience, and is intended to provide a standard Scottish qualification for graduates and others of like calibre with relevant qualifications who will be employed as full-time systems analysts in commerce or administration. The main subjects of the course will comprise principles and practice of systems analysis, programming and software, data processing equipment, systems and management, and commercial applications; while statistics, operational research, econometrics and management accounting will be treated at "appreciation plus" level. It is hoped that the course will be offered in one of the leading colleges of further education in session 1966/67, with the possibility of its being available at certain other main centres later. Shorter full-time or day release courses in systems analysis for those with a substantial amount of relevant practical experience of computers is also envisaged, while some preliminary consideration is being given by S.C.C.A.P.E. to the possibility of introducing a part-time certificate for systems analysts at the level of, and incorporating certain of the existing subjects of, the Scottish Advanced National Certificate in Business Studies.

85. We should also mention a number of short technical college courses at various levels in topics related to computer education (box 2 on the chart). These generally compare well with computer manufacturers' courses. Their function is largely "appreciation", and they cover a wide range, from general appreciation through applications in particular fields and programming to related topics such as business data processing, numerical methods, and operational research. It is conservatively estimated that during 1964/65 more than 2,000 students attended over 50 short courses involving some 25 hours each on various aspects of computer work.

86. Many colleges have an extensive programme of shorter post-qualification courses in the computer field; for example, Kingston-upon-Thames College of Technology has had 300/400 such students annually for two or three years. Of special interest are the topping off courses of various kinds, depending on the

type of job and ranging from a few weeks to six months or even longer. As shown on the chart (box 12), these provide an alternative source of supply for top level computer specialists. Studies to extend facilities in industry for topping off courses are under consideration.

87. Between them these courses cater for students with very different backgrounds. Students taking the City and Guilds of London Institute courses are employees in computer installations. Many, but not all, of those on Higher National Certificate and Diploma courses are sponsored by industry. Systems analysis students are also sent by employers. Degree students come primarily direct from schools, having obtained at least two General Certificate of Education Advanced level passes; others have worked their way up through Ordinary National Certificate and Diploma courses.

(ii) Universities

88. We have already mentioned, in paragraph 76, the universities' contribution to computer education through more generalised courses at both undergraduate and post-graduate level. A number of university institutions also provide opportunities for post-graduate studies in fields specifically related to computer work and this number is growing. The courses of which we have collected details fall into three main groups. First, there are post-graduate courses in computing science at six institutions which in 1965 had 42 students. Secondly, there are courses in numerical analysis and computing at seven universities with 60 post-graduates in 1965. Thirdly, there are post-graduate courses in the human sciences, such as operational research and management studies, which include a substantial element of computer work, which in 1965 had 63 students at five university institutions.

89. We summarise these courses in Appendix 6, showing the numbers of students, and the optimum and maximum sizes for each course. The substantial differences between these last two figures may possibly be related to current difficulties in staffing university computing laboratories, where nearly 30 vacancies among academic and research staff are proving hard to fill. The Ministry of Technology has informed us that it has suggested to the appropriate sub-committee of the Standing Committee of Directors of University Computing Laboratories that they might like to examine the possibility of filling some of their immediate vacancies by recruiting young qualified staff from universities in the United States on a short term basis for some of the more specialist tasks. This would be a useful measure of cross-fertilisation. We understand that this matter is being explored.

90. It is clear from the details in Appendix 6 that most of the courses offered are considerably under-subscribed. Courses in the first two groups are concerned primarily with the scientific application of computers and may not therefore be suitable for the training of computer staff for industrial purposes; though even on those the number of students is far less than the optimum. The courses in the third group are far more likely to have a commercial application and are thus more relevant to our enquiry. It is disturbing to find how slowly some of those in this group are building up to their maximum, or even their optimum, size. The figures we have assembled suggest that there is capacity for over 100 students in this group of courses alone. In fact only 63 of these places were filled in 1965. We comment further on this in paragraph 125 below.

(iii) Private computer schools

91. A number of private establishments offer courses of training for a career in programming or systems analysis. The advertisements of some of these establishments suggest that, after completing their short course of training, a person without higher educational qualifications can obtain a lucrative computer job in industry. These computer schools are not subject to inspection and we cannot comment on their suitability or on their standards of selection or instruction. We think that persons wishing to enter the computer field should also enquire about suitable courses either from a computer manufacturer or a local education authority before commitment to a private course.

V. THE STEPS NEEDED

THE DEMAND

92. It is evident that an increasing knowledge of the principles and potentialities of computers will be required at all levels of the educational system. Appropriate courses will be needed both for those requiring a general appreciation of computers as part of a broader education in business studies, mathematics or science and for specialists who will be working directly with computers. Staff in post will need to be re-equipped to cope with the requirements of computers, and reasonably able young people will have to be diverted from entry into other occupations.

93. All the signs are that in the educational field the pace is quickening. The development in the further education system of the City and Guilds of London Institute course 319, the introduction of its advanced course 320, the increase in enrolments for the Council for National Academic Awards courses in computer science, and the growing emphasis on computer-aligned work in universities, colleges and schools all point in the same direction.

94. Nevertheless by 1970 there is very little time to secure substantial new additions to the output of courses leading to degrees and other courses of similar length. Moreover there may well be limitations in the total numbers of those qualified to enter such courses. Better use needs to be made of the existing provision and steps taken to examine what can be done towards expanding the educational provision for re-equipping those who already have basic educational qualifications or occupy relevant posts inside organisations. This will mean much more planning between employers and educationalists. A good deal of what we have to propose is therefore concerned with liaison between education and industry and with the provision of information.

95. We have seen in Chapter II that industry expects to need by 1970 an extra 200 or so advanced programmers, at least 500 systems designers, 11,000 systems analysts, 19,000 programmers and 16,000 operators, in addition to a number of maintenance staff. These numbers are substantial, but the whole load will not fall on the education service.

96. So far as programmers and operators are concerned we foresee no major difficulty either in recruiting or in training sufficient numbers of such people. Training will largely take the form of manufacturers' and in-service courses, while educational needs can best be met by broadly based courses with an

adequate computer content such as City and Guilds of London Institute course 319. Moreover, the indications are that the computer manufacturers are likely to be able to recruit and train sufficient maintenance staff for their needs for the next few years.

97. The supply of the more creative grades of computer staff is much less satisfactory. In the past there have been virtually no systematic courses, and most present-day systems analysts and designers have been largely dependent on experience which they have brought from other fields, supplemented by in-service training, and by programming and other short basic courses and helpful guidance in planning specific projects all provided by the computer manufacturers. This preparation is becoming increasingly inadequate, and the burden of providing a sufficient supply of systems analysts and designers will fall increasingly upon the educational system. Whereas previously some business "know-how" was a prerequisite for a systems analyst, the new courses will cater largely for staff with limited business experience and will need to impart a sound knowledge of business procedures in addition to the technical skills of systems analysis.

THE CRUCIAL PROBLEM

98. At the outset of this part of our report, therefore, we deal with one specific, urgent call on the educational system over the next few years. All the evidence is that the central and crucial staffing problem is in the systems analyst field. We are convinced that to deal with this what is required is the progressive development of an integrated programme of education and training, of the sandwich type, with successive periods of experience in user organisations and of full-time instruction in college. We would think it desirable—though not necessarily essential—that the great majority of students should be employed and sponsored by computer users, who would co-operate closely with selected colleges in the conduct of the integrated course.

99. We were interested to note that a number of colleges, in consultation with the computer manufacturers and user organisations, have already begun to plan, or at least to think about, courses along these lines; and that these colleges, like us, consider that the college-based part of the programme should ideally be of four to six months' duration, though other patterns of shorter duration including day release are possible, particularly for those with previous programming experience. It appears from these discussions that the content of a full-time six months' course, with six months' practical, for people without such previous experience, might well include:

(*a*) an introduction to programming, with practical experience;

(*b*) introduction to integrated data processing;

(*c*) principles and practice of systems analysis;

(*d*) analysis of the needs and potential needs of management;

(*e*) analysis of business activity, data, and the variety of factors of each type of business activity, including history and development of office organisation and methods;

(*f*) training in network analysis and possibly operational research with a view to ensuring economy of effort as well as full computer utilisation; and

(*g*) the use of a computer to provide information services from such an integrated system.

100. The provision of such courses would impose additional demands on the education service. But except as part of a planned operation with industry there is no guarantee that the places provided would be filled. A key role will be played by the industrial training boards, since they are able to provide the cash incentives to industry to support the courses. The position is such that we are convinced that the Government departments concerned should stimulate the establishment of an expert group representative of educational and user interests as soon as possible to study and advise upon:

(*a*) further suitable programmes for industry-based, non-graduate, student systems analysts, combining in-service training with either a full-time or day release course of further education; and

(*b*) the release by industry of students in sufficient numbers to justify the setting up of such courses in a number of centres.

101. The special problem of providing additional systems designers is no less important. Here the major requirement is for the re-orientation of some existing courses and for the increased provision of post-graduate and of post-experience courses at universities and leading colleges of further education for graduates and persons with similar qualities mostly sponsored by employers. Such courses could well last up to one year. We understand that the launching of a few courses is being actively discussed at present, but some more will be required. It is essential that their full use by industry-sponsored students should be guaranteed in advance, and this implies that their planning from the outset should be in collaboration with the industrial training boards and with industry, who should recognise its responsibility to release employees on salary to take advantage of the courses so planned. We have more to say on this in paragraph 123 below.

PREPARING THE GROUND: PROVISION IN SCHOOLS

102. The necessary groundwork should, however, start much earlier. The educational system has the responsibility both of providing an introduction to computer concepts and principles at various levels within the general educational framework and of enlarging the educational base from which computer staff can be recruited.

103. The response starts in the schools and permeates the whole system. We note the inclusion in an increasing number of school mathematics courses of an introduction to the general principles of computer work. The teaching of flow charting and simple programming techniques will necessitate in our view the provision of desk calculators and other scientific and mathematical equipment on an increasing scale. Some parts of computer equipment which can be operated separately may also provide useful educational opportunities. There is every ground for pushing on with this type of development wherever possible.

104. It has been represented to us that installation of a computer in a school exclusively for its use might well have the effect of distorting the curriculum, and that to multiply such installations would not be a wise or efficient use of educational resources. We see much force in such arguments, and do not envisage that the teaching of particular programming skills will become a function of schools.

105. The use of a travelling computer by groups of schools is another possibility. Such a machine might be of value in providing an introduction to com-

puters where the population is sparse and scattered, but its economic uses are as yet unproven and will need considerable further study. We believe that an experiment in one or two appropriate areas in the use of a travelling computer would supply valuable evidence on its suitability and potentialities.

ACCESS TO A COMPUTER

106. There is much more to be said for organised school access to computer installations elsewhere. These should be "working visits", and not just inspection of computer facilities. The visits should include the running on the computer of programs written in the school for more senior pupils. The ideal situation arises when the school's access is to a computer located in a college of further education, the details having been worked out between the school teacher and the director of the computer unit in the college.

107. It is therefore essential that proper regard should be paid to the needs of schools when considering computer applications and in allocating college computer time. Cases for the provision of computers in colleges already commonly contain an element of school utilisation as part of their justification. It should be realised that if a computer is provided as a result of such a claim, then the school or schools concerned have a moral right to computer time.

108. For colleges of education also, the extent to which a computer would be used is likely to preclude installations specifically for the colleges. In these cases, too, liaison between the college of education and the nearest technical or commercial college with a computer should be established.

PROVISION IN FURTHER EDUCATION

109. Colleges of further education are thus well placed to play a key role. Not only can they act as a focal point for schools and colleges of education, but through their close contacts with local industry they are well able to respond to business needs. While it will not be justifiable to equip all the 600 or so colleges of further education with computers, we are sure that in due course more will need to install their own. It is not for us to propose a specific order of priority, although in our view some such planned development would be advantageous. Particularly where a college is still building up its range of computer courses, it may be better for the college to strengthen its industrial links by arranging for students and senior pupils to have access to a commercial computer rather than to install one of its own.

110. In Chapter IV we said that computer education was of two broad types: the provision as part of more generalised courses of an appreciation of a computer's potentialities or an understanding of computer concepts and techniques; and the provision of a more specialised education and training for those working directly with computers. This suggests three kinds of further education course: first, general appreciation courses for the senior executive, which may in some cases form part of business management courses; secondly, courses for those who are not engaged full-time on computer work but who are employed in specialist fields, such as accounting, which are increasingly being affected by the application of computers (such courses may be quite short and will increasingly form part of the professional training of such people); and thirdly, courses for those who have to be closely concerned with the detailed operation of computers to ensure their effectiveness in a particular context.

111. If the students are to get the maximum value from such courses, attention needs to be paid to ensuring that the background knowledge from which each group of students starts is of about the same level. If it is not, a "scatter" tends to develop as the course proceeds with the result that the students with the more elementary knowledge are left behind.

(i) Courses for senior executives

112. If industry is to be persuaded to make full and effective use of a computer's potentialities, it is essential that educational establishments should expand their provision of appreciation courses aimed specifically at the senior executive. This group covers not only leading men in large and medium sized companies who can spare only one or two days for a course to familiarise themselves with the potential of computers, but also men in or moving towards senior management who will be responsible for policy decisions in average sized companies over the next decade.

113. Experience shows that senior people are not willing to join a course of a technical nature lasting several weeks or months aimed mainly at junior or younger colleagues, and so cannot be expected to take up any unfilled places on existing courses of that type. Special courses are therefore needed. The immediate support of the business schools by industry suggests that senior executives can be attracted to a compressed course in congenial, preferably residential, surroundings. Some courses of this kind are available, and might reasonably be extended in the business schools, in appropriate university departments and in leading technical colleges. Sometimes the greater problem is to persuade industry to use them. Where this is so, attention should be given to the most attractive way of mounting them. A full-cost fee could appropriately be charged.

(ii) Non-specialist courses with a computer content

114. It is important that persons in professional and executive occupations, in which computers are making an increasing impact, should be alive to computer possibilities in their particular field and be able to contribute intelligently to their development. Obvious fields are accountancy, organisation and methods, and engineering; but with the spread of computerisation most administrators and professional men will be helped by the same basic knowledge. This demands varying degrees of general and specialised knowledge of computers, according to the particular specialism and the extent of likely involvement in computer projects.

115. Increasingly, as has been shown in Chapter IV, degree, professional and higher technician courses are being introduced or revised with an appropriate element of computer study. We doubt, however, whether the process of syllabus revision to take account of computer developments has yet gone far and fast enough, and we urge those responsible, especially in the field of business studies, to keep this matter under constant review. For persons already holding professional or specialist qualifications much may be achieved by conferences, lectures and general appreciation courses, but there is also a need, especially for those who will be closely concerned in computer projects in their own particular field, for more systematic courses, possibly in the form of an endorsement to the existing qualification or, where this is not possible or necessary, by *ad hoc* courses of a specialist nature. We look to professional institutions, examining bodies and colleges to give further attention to these needs.

(iii) Specialist computer courses

116. As computers represent a relatively new industrial development, it is hardly surprising that courses for specialist computer staff are also in the early stages of establishment and growth. The courses for the City and Guilds of London Institute schemes 319 and 320 are in their infancy. Eight colleges produced candidates for the junior examination in 1966; 32 colleges were then participating; about 20 more offered the course in September 1966. This is a measure of its growth. Course 319 is an educational scheme designed for, and suitable for, operators and junior programmers whatever their background, and provides a foundation for further progress for the brighter people. Course 320 also seems likely to be an effective course for programmers with the potential to become systems analysts.

117. For systems analysts and designers, the need for the rapid development of suitable courses is acute and we are in no doubt that the colleges of further education should play an important part in meeting this need. We have already referred (paragraphs 99–101) to the urgent need for the development, in collaboration with industry, of courses of sandwich or post-experience type for systems analysts and designers. In addition, developments already taking place in the Higher National Certificate and Diploma in mathematics, statistics and computing will make a useful contribution, while first degree courses of the Council for National Academic Awards will provide an increasingly important source of recruitment for posts in systems analysis and design.

SUPPLY AND TRAINING OF TEACHERS

118. The spread of computer knowledge in schools and the expansion of specialist computer courses in colleges of further education on the scale envisaged means that a substantial increase in the number of teachers able to deal with this will be needed. As computers are a recent development, relatively few teachers of computer subjects in colleges of further education have the requisite practical experience of computer work. H.M. Inspectors of Schools have organised some teachers' short courses, but successful though they have been they have been on too small a scale to have made a great impact. Some computer manufacturers have offered courses to teachers at minimal costs; but these have had limited success because the teachers have frequently had to meet a substantial part of the cost.

119. We think that all concerned should give urgent attention to increasing the supply of teachers with appropriate computer knowledge. Local education authorities should consider the secondment of teachers to attend suitable short courses for specialist computer staff. In the short term, the Department of Education and Science and local education authorities should consider the possibility of sponsoring, with the help of the computer manufacturers, special courses for teachers followed by experience with computers. They could be organised on a regional basis, and the Regional Advisory Councils for Further Education might well consider initiating such courses, as was suggested by the Department of Education and Science in 1964. Meanwhile, every effort should be made to enlist the support of industry in releasing or seconding experienced computer staff for full or part-time teaching appointments, particularly over the critical next few years.

120. This is a particularly appropriate moment to encourage any further developments which may be necessary in university computer courses. The universities are in the process of determining their priorities for the next quinquennial settlement. Management education, which includes the appreciation of computers, is being expanded, especially in the business schools. The implementation of the call in the Flowers Report on Computers for Research* for a substantial computer programme for universities and research councils has offered the prospect of much enlarged computer facilities. Although the case for this is based on research needs, the additional facilities cannot fail to have an impact on university teaching programmes.

121. The Flowers Working Group themselves emphasised the need for computer time for university teaching. In paragraph 25 of their report, after underlining the importance of the computer as a research tool, they said that "Equally an understanding of computers and their applications must be given to many undergraduates whose lives and careers will be affected in varying degree as the use of computers in government, commerce, medicine, industry and research continues to grow". Evidence submitted to them suggested that a very modest allocation of computer time for teaching purposes could enormously increase a university's capacity for teaching science-based subjects. We very much hope that universities will be able to allocate a measure of computer use for teaching purposes in the ways suggested.

122. First degree courses in mathematics, which include aspects of computer work, are continuing to expand in number. But in view of the need for advanced programmers and systems designers, the most significant contribution of the universities and business schools to computer education will be at post-graduate level. They are also well placed to provide the appreciation courses for higher management we have already mentioned in paragraph 113. In these circumstances we consider that well grounded developments for high level courses, especially at the post-graduate and post-experience levels, qualifying those who pursue them for practical development with computers—primarily as advanced programmers, systems designers and systems analysts—should be accorded high priority by the various bodies whose responsibility it is to consider the above developments.

123. We have noted in paragraph 88 and Appendix 6 that a number of post-graduate courses with a computer content now exist. Some of these are designed to have a predominantly scientific application and, whilst the need for these will continue and may indeed grow, by their nature they are not likely to make a major contribution to meeting the needs discussed in this report. Some of the post-graduate courses, however, especially those with an operational research or management content, are of value to those seeking careers in systems analysis and design in commerce, industry and administration. Here at least would seem to be a basis which, if developed, could go far to meet the large estimated requirement for systems designers and other highly qualified staff to work with computers.

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* A Report of a Joint Working Group on Computers for Research. Cmnd. 2883, H.M.S.O., 6s. 6d.

124. But this alone is not enough. The need for systems designers and other senior computer staff is likely to be so acute that, even if the universities were to fill all places on their existing post-graduate courses which have a substantial computer element and even if industry maintains its present training programme, there will still remain a shortage in these vital grades which cannot be met by the higher educational system by 1970 with the present provision. The Software Committee of the Advanced Computer Techniques Project of the Ministry of Technology has recently arranged a three-week pilot course in advanced programming at Imperial College of Science and Technology, which was well received; and it is hoped to publish lecture notes in book form by H.M. Stationery Office in order to encourage the establishment of similar courses elsewhere. So far as systems designers are concerned, we have already suggested (paragraph 101) that there is an urgent need for the re-orientation of some existing courses and for the increased provision of post-graduate and post-experience courses. It is evident that the universities can play a major part in developments of these kinds. We hope therefore that they will take full account of these pressing needs when deciding their priorities and submitting their programmes for the next quinquennium.

125. A further cause for concern is that the post-graduate courses with a computer content do not yet appear to attract anything like the full number of students that they could accommodate. This may be because some of them have been started only in the last year or two; and there may be problems of student support (which we mention below). It takes time properly to establish new activities of this sort. By the same token, it appears to us probable that universities and colleges from their side, and industry, commerce and administration from theirs, may still have some way to go in devising the courses best suited for the practical workers at a high level in this field who are so badly needed.

126. We consider that an expert survey of the position, which we hope the University Grants Committee would be willing to arrange, would be a possible way of tackling this problem. Such a survey would have as its objective the reasons for the apparent lack of support for the existing courses, and would take into account both the content of courses (whether post-graduate or post-experience) best suited to the needs of industry, commerce and administration and the nature of existing courses in the light of these requirements. It would then be possible to establish whether the bias in some existing courses towards scientific and technological research required additional courses of a more practical nature, and how far re-orientation of existing courses was practicable and desirable. The results of such a survey should provide the basis for collaboration between computer manufacturers, users, and the universities and colleges to stimulate increased support for suitable courses.

127. The work already done in this field by various bodies, including the Ministry of Technology's Consultative Group on Computer Staff which is representative of the main computer manufacturers and consultants, would provide a valuable point of departure for such a survey. We understand that the Group has already given thought with university institutions to the type of post-graduate and post-experience courses which would be most suitable for systems designers.

STUDENT SUPPORT

128. An important factor in the expansion of computer courses is the measure of financial support available for students. In England and Wales the current arrangements for awards from public funds for post-graduate study are set out in Circular 14/66* of the Department of Education and Science. Similar arrangements apply in Scotland and Northern Ireland. Research council awards are available for students on accepted courses. The Science Research Council bases its awards on the students' qualifications and is prepared to support students with a first or second class honours degree in science, engineering or mathematics, or an acceptable equivalent qualification, on the university courses with a substantial computer element listed in Appendix 6, and has recently extended its awards scheme to allow employers to top up awards to salary levels. This should make attendance at such courses far more attractive to those with degrees in science, engineering or mathematics who have already started on an industrial or commercial career.

129. Other post-graduate award schemes, however, tend to base their awards on the students' subject of study. Thus Social Science Research Council awards are restricted to students taking social science courses, whatever their first degree. There are therefore at present some difficulties in supporting post-graduate students in computer subjects whose degrees are not in science, engineering or mathematics. Since, for a good deal of computer work, even in the higher reaches, only an elementary knowledge of mathematics is necessary, we think it important that suitable students with first degrees in non-scientific subjects should be eligible for research council awards on this type of course. It is hoped that these difficulties will soon be resolved satisfactorily by the Science Research Council and the Social Science Research Council.

130. Where a post-graduate student does not qualify for a research council award, he may be eligible for a discretionary award from his local education authority (in Scotland, from the Scottish Education Department). Circular 14/66 expresses the Secretary of State's hope that where a post-graduate student is ineligible for a research council award, as, for example, for a second first degree or for a course of a mainly vocational or professional nature designed to fit him for a particular calling, local education authorities will be prepared to consider an application for an award sympathetically.

131. Circular 4/66† of the Department of Education and Science similarly reminds authorities of their duties and powers under the Education Act 1962 to make awards for courses, both full-time and part-time, at first degree level, and expresses the Secretary of State's hope that authorities will be prepared at this level also to give sympathetic consideration to an application for a discretionary award in appropriate cases. It is understood that awards for Higher National Diploma courses are also readily available.

THE INDUSTRIAL TRAINING ACT

132. The Industrial Training Act, 1964 was designed to encourage the training and associated further education of those already in employment. Industrial

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* Awards for Postgraduate Study. Department of Education and Science, unpriced.

† Awards to Students. H.M.S.O., 2s. 6d.

training boards, which are being rapidly established under the Act, have a duty to assess the needs of the industries which they cover; and, by means of differential grants, can actively encourage employers to send students on courses and to make available facilities for the practical training of college-based sandwich course students. These new arrangements will play a vital part in computer education: indeed, in the long run, these incentives are likely to be quantitatively of even greater significance than the post-graduate awards. Many boards are prepared to finance training not only at the supervisory and lower levels but also in the highest reaches of management. We hope that the boards will encourage employers to release staff not only at lower levels but also at a level where computer education courses are likely to have a real impact on future policy.

LINKS BETWEEN INDUSTRY AND EDUCATION

133. We have repeatedly stressed that close liaison between industry and education is crucial if computer education is to meet industrial needs in practice as well as theory. Technical colleges already have a long tradition of contact and liaison with local industry which should be helpful and universities are rapidly developing similar connections. Industry is represented on the colleges' governing bodies, business men are engaged as part-time lecturers and teaching staff pay frequent visits to industrial organisations. But participation by business in educational developments could be even more direct than this. Colleges and universities need a clearer idea of the particular needs of industry when drawing up syllabuses, and industry should help in publicising the arrangements offered by the colleges and universities. Industry must be willing to release key people to attend the courses, both as students and as occasional lecturers. Finally the success of the sandwich course scheme depends on industry being prepared to give students the essential experience of industrial conditions to complement their college course. All this applies as much to computer education as to other fields of industrial activity.

134. There are several ways in which such closer co-operation can be fostered. The functions of the Regional Advisory Councils for Further Education, which include representatives from constituent local education authorities, universities, technical colleges and industry are very much in point. They include the ascertainment of the needs of industry, the establishment and co-ordination of appropriate courses and the dissemination of information on current problems. The machinery of the Department of Economic Affairs, through the Regional Economic Planning Councils on which both education and industry are represented, provides another possible channel. In Scotland, the Scottish Council for Commercial, Administrative and Professional Education is well placed to foster co-operation between educational and user interests in business and administration in ascertaining needs and devising appropriate computer courses.

135. The Central Training Council established under the Industrial Training Act, 1964 to advise the Minister of Labour on industrial training matters has set up a Commercial and Clerical Training Committee which has expressed considerable interest in the education and training of computer staff. The industrial training boards themselves will increasingly deploy expert staff in the field able to advise industry on opportunities for training and are in touch, where appropriate, with the Regional Advisory Councils for Further Education. Industrial liaison officers of the Ministry of Technology who advise businesses, especially those of

small and medium size, on the latest technological developments are also well placed to advise on computers and computer staff education.

136. In the university field itself, following the 1965 Home Universities Conference, machinery has been set up for joint consultation between the Committee of Vice-Chancellors and Principals and the Confederation of British Industry. A standing committee has been established to meet twice a year to discuss matters of common concern.

137. The National Computing Centre, established under the auspices of the Ministry of Technology, has amongst its tasks the provision and encouragement of training in systems analysis, programming principles and computer applications. The Centre is an independent corporation in which industrial organisations will participate as subscribers and in this way a further link will be maintained between industry and training activities.

138. These various arrangements, many of them newly introduced, provide ample opportunities for industry and education jointly to exploit the opportunities that exist. We believe that to an increasing extent those concerned are already giving attention to consultation and mutual help over a broad front; and hope that in the field of computer education full advantage will be taken of such liaison facilities to devise suitable education courses.

DISSEMINATION OF INFORMATION

139. If the liaison arrangements are to function effectively and full use is to be made of the computer courses provided, school leavers, post-graduates and employers all need to be made systematically aware of the range of courses opening up for them. It is, however, difficult to obtain an overall picture of the opportunities available. Many short courses are arranged to meet a particular demand from industry, commerce or administration, and the pattern is constantly changing.

140. We have been glad to learn that the British Computer Society (from whom we have had evidence) is collecting and keeping up to date information about computer courses provided by universities, colleges and other bodies. It has already published a valuable analysis of the courses available up to the beginning of the academic year 1966/67*, and believes that most of the courses with a substantial computer content have been included, though probably a few with a small element have been missed. The British Computer Society and the National Computing Centre are actively concerned with the evaluation of these courses.

141. We have been much helped by the pioneering work of the British Computer Society in assembling this information. But so rapidly is the picture changing that we consider that an authoritative guide to computer courses should be prepared annually. We think that such a guide should classify the courses by the job category to which they lead and show the required entry qualifications. It should be published early in each new year and made available to educational institutions, the business world and public authorities. Since this would involve the co-operation of all educational institutions and analysis by experts of the

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* List of Computer and Associated Courses. The British Computer Society, September 1965, 4s. Supplement, December 1965, 2s. 6d. Supplement 2, August 1966, 4s. post free. (All three lists, 7s. 6d. post free.)

information supplied, we suggest that it may be appropriate in due course for the Ministry of Technology to ask the National Computing Centre to undertake the task of compiling the guide. Enquiries about shorter courses should continue to be referred direct to local education authorities.

142. Although a national information exercise of this kind will be important the primary responsibility for publicising courses must still rest with each educational institution. Most educational establishments produce brochures setting out the facilities available, and we hope that those which rely mainly on personal approaches to industry will see that all the lines of communication mentioned above will be considered for this purpose and that small and medium sized businesses are not overlooked.

CAREERS GUIDANCE

143. The Ministry of Labour is considering the possibility of preparing a booklet on computer employment in their careers advice series; meanwhile the British Computer Society has again been most helpful in publishing a careers booklet*, which the Ministry is arranging to circulate to youth employment officers. We welcome this; we are also glad that the Society is proposing to publish annually a computer education review, covering courses, careers, reading matter, films, training equipment†, etc., which will be available to all who are interested, and is in direct touch with chief education officers throughout the country.

144. When this kind of information becomes available, school careers masters and youth employment officers should be in a better position to give advice on careers in computers, on the entry qualifications needed and on the education and training which is available. It may be desirable for local education authorities to supplement the literature by arranging short courses and conferences for careers masters and youth employment officers so that they will be able to give school leavers first-hand advice on what should be a growing and exciting range of computer careers offering excellent prospects for those with the right personal qualities.

CONCLUSION

145. We have already summarised, in paragraph 22, the steps which we consider are necessary and possible in the immediate future. They are in a sense no more than a marshalling, at certain critical points, of movements that are already in progress. Nevertheless we consider that they make up a unified strategy for the use of resources which either exist or are already committed. Many different agencies are concerned here, and it is only by their co-operation at working level that real progress is going to be made on the proposals to which we attach most importance. In particular we cannot over-emphasise the importance of the nexus between industry and education in this field. Unless the educational institutions respond to the requirements of industry, and unless industry clearly notes its needs and supplies the students, the educational effort will remain less than fully effective.

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* Careers with Computers. The British Computer Society, 3s. 6d. (4s. post free).

† The British Computer Society have also published Digital and Analogue Training Aids, 10s. 6d. post free.

Appendix 1
(paragraph 53)

OUTPUT OF MATHEMATICIANS

(a) *Graduates in United Kingdom*

(i) *University Honours Graduates*

1. The University Grants Committee's annual statistics include a table showing the main subjects in which honours degrees were obtained at universities in Great Britain. As an annex to this appendix, we include an extract from its tables to show the number of honours graduates in mathematics, or in mathematics combined with another subject, for each year from 1959 to 1965. Over this period, the number of honours degrees in mathematics has risen from 473 to 1,063 (nearly 125 per cent increase), and in mathematics combined with another subject from 72 to 227 (or over 215 per cent). The annex shows separately the figures relating to Scottish universities, where the increases have also been rapid. Equivalent figures for Queen's University, Belfast, whose statistics are not included in the University Grants Committee's tables, are shown in a footnote to the annex.

(ii) *All Graduates and Diplomates*

2. A similar trend is apparent if the picture is broadened to include both honours and pass degrees in mathematics as well as diplomas in technology, which are being replaced by degrees of the Council for National Academic Awards. These figures are shown in the following table.

Mathematics Degrees and Diplomas in Technology
(Great Britain only)

Year	University degrees, including external degrees taken in further education establishments	Diplomas in technology and degrees of the Council for National Academic Awards	Total
1958	594	—	594
1959	681	—	681
1960	880	—	880
1961	889	7	896
1962	901	29	930
1963	1,056	29	1,085
1964	1,296	60	1,356
1965	1,581	79*	1,660*

Estimated*

3. The university degree figures are based on information supplied by appointments officers and may not be precise. They include both mathematics and statistics degrees, but the statistics graduates represent only a small proportion of the totals. In 1962, there were only 16, in 1963 38, in 1964 54, and in 1965 66 out of 1,581. Of the 1,515 mathematics graduates in 1965, 104 came from Scottish universities.

4. In addition to those included in the above table, a substantial number of candidates have taken mathematics associated with a wide range of other scientific subjects. It is estimated that in 1965, in United Kingdom universities, over 1,600 students graduated in mathematics combined with another subject, 532 of them with physics. Of these 532, 109 came from Scottish universities.

5. In addition to the graduates mentioned in the above paragraphs, about 25-30 students graduate with honours in mathematics each year at Queen's University, Belfast.

(b) *Further Education in England and Wales*

6. In further education, mathematics and allied studies, conducted in an atmosphere of business and commerce, have been increasing in recent years and student numbers are still rising. A substantial part of the rapid increase has been in the colleges of advanced technology which are moving into the university sphere, but in the remaining colleges three- or four-year sandwich courses leading to degrees of the Council for National Academic Awards are expected to play a valuable role over the next few years in the field of mathematics and/or business mathematics. As mentioned in chapter IV, in 1966 215 students enrolled at six colleges for the Council's B.Sc. degrees in computer science and another 104 on B.Sc. mathematics courses. Mathematics is also included in many National Certificate courses.

(c) *Further Education in Scotland*

7. Mathematics is a compulsory subject in many National Certificate courses. The National Certificate in mathematics, at Ordinary and Higher level, designed to provide mathematics technicians for industry, was launched in 1964 and over 110 students are at present engaged on the course.

(d) *Further Education in Northern Ireland*

8. Mathematics is a subject of many of the Ordinary and Higher National Certificate and Diploma courses. As from 1966, Higher National Certificate and Diploma courses in mathematics, statistics and computing will be available.

(e) *Colleges of Education in England and Wales*

9. Of 29,756 students admitted to colleges of education in England and Wales during the academic year 1965/66, 2,066 are taking mathematics as a main subject; 728 of these are taking purely secondary courses of professional training, and 756 students are on courses extending over both junior and the lower secondary age ranges.

(f) *Colleges of Education in Scotland*

10. Of 4,435 students admitted to colleges of education in Scotland during the academic year 1965/66, 121 are taking mathematics as a main subject and 46 are taking mathematics with subsidiary science subjects.

(g) *Colleges of Education in Northern Ireland*

11. Of the 554 students who qualified for the Teacher's Certificate in 1965, 101 passed in mathematics as a main subject (three-year courses) and a further 7 successfully completed the fourth year semi-specialist course in mathematics. 33 of the 108 had followed mathematics courses designed for secondary teachers.

(h) *School Examinations in England and Wales*

(i) *General Certificate of Education*

12. The main mathematical qualification held by secondary school leavers in England and Wales is the General Certificate of Education, at Advanced or Ordinary level. The same qualification can be obtained by study at many colleges of further education. The rapid increase in the number of passes, at both levels, over the past decade is shown in the following table.

General Certificate of Education passes in mathematics

	1954	*1959*	*1964*
Advanced level	13,017	22,921	34,991
Ordinary level	71,183	106,178	159,517

13. The Advanced level statistics include a number of candidates who have been successful in more than one paper in mathematics and who have been counted more than once; but the number of passes over the decade to 1964 has risen by about 170 per cent. At Ordinary level the passes represent a growing proportion of the total number of passes in academic subjects—13·5 per cent in 1954 and 14·8 in 1964—and it is estimated that about 21 per cent of each age group is now achieving a pass in mathematics compared with only about 13 per cent in 1954.

(ii) *Certificate of Secondary Education*

14. With the introduction of the Certificate of Secondary Education examination in 1965, a greater number of young people have been able to obtain a formal qualification in mathematics which at the highest level will bear comparison with the Ordinary level of the General Certificate of Education examination. Over 43,000 candidates sat the examination in either mathematics or arithmetic in 1965, the first year, when it was not held in all areas.

(j) *School Examinations in Scotland*

15. The Higher grade examination in Scotland is taken one year after the Ordinary grade examination but the standard is much nearer that of the Advanced level of the General Certificate of Education than that of the Ordinary level. The figures for passes are:

	1954	*1959*	*1964*
Higher Grade	2,932	3,950	5,932

16. Prior to 1962 pupils in the fifth year of their secondary course (i.e. at 17 in Scotland) normally took a Lower grade examination for the Scottish Leaving Certificate. In 1962, however, that examination was replaced by an examination for pupils in their fourth year for the Ordinary grade of the Scottish Certificate of Education. Thus the Ordinary grade standard is rather lower than that of the former Lower grade but it approximates to, and is certainly no lower than, that of the Ordinary level of the General Certificate of Education. Before 1962 only school pupils were allowed to sit for the Scottish Leaving Certificate, but with the introduction of the Scottish Certificate of Education individuals attending recognised further education establishments or sponsored by education authorities or certain other bodies became eligible in certain circumstances to sit. As a result of these changes the relevant numbers of passes have increased as follows:

	1954	*1959*	*1961*
Scottish Leaving Certificate Lower grade . .	2,912	3,590	5,033

	1962	*1963*	*1964*
Scottish Certificate of Education Ordinary grade .	15,238	14,925	16,171

(k) *School Examinations in Northern Ireland*

17. The number of passes in mathematics in the Northern Ireland General Certificate of Education (which is of equivalent standard to the General Certificate of Education in England and Wales) during the last three years is shown in the following table:

	1963	*1964*	*1965*	
Advanced level .	1,139	1,009	739	
Ordinary level .	5,060	5,086	4,646	(in mathematics)
			2,289	(in additional mathematics)

18. In addition, a number of pupils in Northern Ireland schools pass in mathematics in General Certificate of Education examinations conducted by examining boards in England. No precise figures are available, but it is estimated that they would increase the above figures by at least 5 per cent at each level. They have already been included in the figures in paragraph 12 above.

Annex to Appendix 1

HONOURS GRADUATES FROM UNIVERSITIES IN GREAT BRITAIN

(Scottish figures in brackets)

	1959	1960	1961	1962	1963	1964	1965
Mathematics . .	473(14)	593(18)	631(29)	593(16)	673(17)	892(41)	1063(58)
Maths. Applied . .	3(1)	23(4)	23(8)	36(4)	48(13)	23	12
Maths. Pure . .	—	—	—	—	—	—	44
Maths. Pure and Applied	—	—	—	—	4	—	—
Maths./Chemistry .	3	2	5	4	2	11	13
Maths./Philosophy .	—	—	3	3	4	40(35)	32(25)
Maths./Physics . .	48(32)	52(21)	67(26)	46(26)	32(16)	36	27
Maths./Statistics . .	—	—	—	—	1	8	43
Mathematical Physics .	5(1)	7(3)	8(1)	17(3)	14(2)	11(3)	15
Mathematical Science .	6(6)	7(7)	6(6)	7(7)	12(12)	21(21)	22(22)
Mathematical Statistics	—	—	—	5	9	7	9
Maths./Other Subject .	7(1)	5(2)	7(3)	5(2)	13(1)	7(4)	10(1)
TOTAL . .	545(55)	689(55)	750(73)	716(58)	812(61)	1056(104)	1290(106)

Source: University Grants Committee's Annual Returns from Universities and University Colleges in receipt of Exchequer Grant.*

NOTES: (1) The Scottish figures are included in the Great Britain figures.
(2) The equivalent figures for Queen's University, Belfast (not included in the above table) are:

Mathematics	7	27	19	14	19	22	27

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* For the Academic Year 1964-65. Cmnd. 3106, H.M.S.O., 8s. 6d.

Appendix 2
(paragraph 62)

COMPUTERS IN COLLEGES OF FURTHER EDUCATION, INCLUDING THOSE APPROVED UP TO 31ST JULY, 1966

(arranged by geographical county)

England	*Computer*
Devon:	
Plymouth College of Technology	PDS 1020
Durham:	
Sunderland Technical College	Elliott 803
Essex:	
Thurrock Technical College	ICT 1201
Gloucestershire:	
Bristol College of Commerce	ICT 1202
Cheltenham, The North Gloucestershire Technical College	ICT 1901
Hampshire:	
Portsmouth College of Technology	Elliott 803
Hertfordshire:	
Hatfield College of Technology	Elliott 803
Letchworth College of Technology	NHECTA II
Watford College of Technology	Elliott 402
Huntingdonshire and Peterborough:	
Peterborough Technical College	Zebra
Kent:	
Chatham, Medway College of Technology	MCS 920
Lancashire:	
Blackburn College of Technology and Design	Sirius and Zebra
Liverpool College of Technology	Elliott 803
Manchester, John Dalton College of Technology	Elliott 803
Oldham Municipal Technical College	Sirius
Leicestershire:	
Leicester Regional College of Technology	Zebra and Honeywell H200
London (Greater):	
Barking Regional College of Technology	Elliott 4100
Croydon Technical College	ICT 1201
Enfield College of Technology	IBM 1440 and Honeywell H120
Greenwich, Woolwich Polytechnic	Sirius
Islington, Northern Polytechnic	Elliott 4100 (1)
Kingston-upon-Thames College of Technology	Elliott 4100
Newham, West Ham College of Technology	Pegasus I and IBM 1130
Westminster, Regent Street Polytechnic	IBM 1620
Northamptonshire:	
Northampton College of Technology	ICT 1202
Northumberland:	
Newcastle upon Tyne, Rutherford College of Technology	IBM 1620 Mk. II
Staffordshire:	
Stafford, Staffordshire College of Technology	Deuce (2)
Warley, The Chance Technical College	ICT 1202
Wolverhampton College of Technology	IBM 1620 Mk. II

Surrey:	
Weybridge, Brooklands County Technical College	Pegasus
Sussex:	
Brighton College of Technology	ICT 1301 and IBM 1401
Warwickshire:	
Coventry, Lanchester College of Technology	Elliott 803
Rugby College of Engineering Technology	Elliott 803B
Yorkshire, E.R.:	
Kingston upon Hull College of Technology	ICT 1202 (1)
Yorkshire, N.R.:	
Cleveland Technical College	Mercury
Middlesbrough, Constantine College of Technology	IBM 1620 Mk. II
Yorkshire, W.R.:	
Sheffield College of Technology	IBM 1130
Wales	
Flintshire:	
Connah's Quay, Flintshire Technical College	IBM 1440
Glamorgan:	
Treforest, Glamorgan College of Technology	IBM 1130
Monmouthshire:	
Newport and Monmouthshire College of Technology	Elliott 803
Scotland	
Aberdeen, Robert Gordon's Institute of Technology (3)	Elliott 4100
Dundee Institute of Art and Technology (3)	Elliott 4100
Galashiels, Scottish Woollen Technical College (3)	Elliott 903
Northern Ireland	
Belfast Municipal College of Technology	Elliott 803B

NOTES: (1) Computer hired.

(2) Free loan.

(3) The three colleges in Scotland are all central institutions.

(4) On 31st July, 1966, the provision of computers at four colleges in England and one in Scotland was under consideration.

Appendix 3
(paragraph 76)

COMPUTERS IN UNIVERSITIES AND COLLEGES OF ADVANCED TECHNOLOGY, INCLUDING THOSE APPROVED UP TO 31st JULY, 1966

University or College	*Computer*
England	
Aston University in Birmingham	Elliott 803
Battersea College of Technology (5)	Sirius and Elliott 503
Birmingham University	KDF 9
Bradford Institute of Technology (5)	Zebra and ICT 1909
Bristol College of Science and Technology (5)	Elliott 803
Bristol University	Elliott 503
Brunel University	Elliott 803
Cambridge University	Atlas
Chelsea College of Science and Technology (5)	Elliott 803
City University	Pegasus and ICT 1905
Durham University	Elliott 803
Essex University	ICT 1909
Exeter University	Elliott 803
Hull University	Elliott 803
Keele University	IBM 1620 (1)
Lancaster University	ICT 1909
Leeds University	KDF 9
Leicester University	Elliott 803
Liverpool University	KDF 9
London University:	
Imperial College of Science and Technology	Atlas (2) and IBM 7090
University College	
Loughborough University of Technology	IBM 1620 and Argus 104
Manchester University	Atlas (3) (4)
Manchester University Institute of Science and Technology	Argus (4)
Newcastle upon Tyne University	KDF 9
Nottingham University	KDF 9 (4)
Oxford University	KDF 9
Reading University	Elliott 803
Salford, Royal College of Advanced Technology (5)	KDF 9
Sheffield University	Mercury
Southampton University	Pegasus and ICT 1907
Wales	
University of Wales:	
Aberystwyth	IBM 1620
Bangor	Elliott 803
Cardiff	Zebra
Swansea	IBM 1620
Welsh College of Advanced Technology	Zebra and Elliott 803

Scotland	
Aberdeen University	Elliott 803
Edinburgh University	(4)
Glasgow University	KDF 9
Heriot-Watt University	Sirius
St. Andrews University	IBM 1620 and Zebra
Strathclyde University	Sirius (3)
Northern Ireland	
Belfast, Queen's University	ICT 1905

NOTES: (1) Privately owned.

(2) Shared with commercial company.

(3) Bought with own funds.

(4) Manchester University Institute of Science and Technology, Nottingham University and Edinburgh University each has a link with Manchester University's Atlas.

(5) Since 31st July, 1966, Chelsea College of Science and Technology has become a constituent college of London University; Battersea College of Technology has become the University of Surrey; Bradford Institute of Technology the University of Bradford; and Bristol College of Science and Technology the Bath University of Technology. The Royal College of Advanced Technology, Salford, has applied for a charter to become the University of Salford.

(6) The provision of computers for universities is under consideration by the Computer Board.

Appendix 4
(paragraph 78)

CITY AND GUILDS OF LONDON INSTITUTE'S COURSES FOR COMPUTER PERSONNEL

The City and Guilds of London Institute's course 319 leading to the Certificate for Computer Personnel is available in the following 32 colleges, which for convenience have been arranged by geographical county. The eight colleges marked with an asterisk entered students for the first examination in the summer of 1966. About 20 more colleges offered the course in September 1966.

England

Devon:	Barnstaple, North Devon Technical College.
Essex:	*Chelmsford, Mid-Essex Technical College and School of Art.
	Colchester, N.E. Essex Technical College and School of Art.
Gloucestershire:	*Bristol College of Commerce.
	Cheltenham, The North Gloucestershire Technical College.
Hampshire:	Bournemouth Municipal College of Technology and Commerce.
	Portsmouth College of Technology.
	Southampton College of Technology.
Hertfordshire:	*Boreham Wood College of Further Education.
	*Letchworth College of Technology.
Lancashire:	Blackburn College of Technology and Design.
	Salford Technical College.
	Widnes College of Further Education.
Leicestershire:	*Leicester Regional College of Technology.
London (Greater):	Harrow Technical College and School of Art.
	Hounslow, Isleworth Polytechnic.
	*Wandsworth Technical College.
Northamptonshire:	Northampton College of Technology.
	Peterborough Technical College.
Staffordshire:	Stafford, Staffordshire College of Technology.
	Warley, The Chance Technical College.
Surrey:	*Weybridge, Brooklands County Technical College.
Warwickshire:	Solihull Institute of Further Education.
Yorkshire, N.R.:	Middlesbrough, Constantine College of Technology.
W.R.:	Sheffield College of Technology.

Wales

Glamorgan:	*Cardiff, Llandaff Technical College.
	Port Talbot College of Further Education.
Monmouthshire:	Newport and Monmouthshire College of Technology.

Scotland

Dundee Commercial College.
Edinburgh, Napier Technical College.
Glasgow, Central College of Commerce and Distribution.

Northern Ireland

Belfast Municipal College of Technology.

Appendix 5
(paragraph 82)

SANDWICH COURSE SYLLABUSES

A. *Brighton College of Technology: Honours Degree Course in Computing and Data Processing*

Entrance Requirements: These are not strictly defined, but most students admitted have obtained Advanced level passes in pure mathematics and have passed one or more programmers' aptitude tests at a high standard. There is a long interview and school reports are considered. A candidate not possessing an Advanced level pass in a mathematical subject may apply for admission.

For students holding an Ordinary National Certificate or Ordinary National Diploma in science or engineering, the entry requirements are a minimum of 75 per cent in mathematics in the final year and at least 60 per cent in physics and two other final engineering or science subjects. At the same time a good record of work in liberal studies will be required.

At the end of the first term each student must satisfy the examiners in internal examinations in mathematics and computation (two papers), statistics and digital computing.

Examination Arrangements:

Part One—

Two papers each in mathematics and computation (to include questions on sets, logic, Boolean algebra and information theory), and statistics.

One paper each in economics and accountancy.

One four-hour paper in digital computing.

Part Two—

One four-hour problem paper in each of mathematics and computation, statistics and operational research.

One three-hour paper in economics and *either* analogue computing *or* advanced accountancy.

B. *Hatfield College of Technology: Bachelor of Science in Computer Science*
Entrance Requirements: Either

(*a*) a General Certificate of Education in five subjects including two subjects at Advanced level, one of which must be mathematics; or

(*b*) an Ordinary National Diploma or Certificate in science or engineering with a mark of at least 60 per cent in mathematics; or

(*c*) other relevant qualifications.

Applicants will be interviewed and may be required to sit an entrance examination.

At the end of the second term of the first year students are required to sit an internal qualifying examination.

Examination Arrangements:

Part One—

(i) Two three-hour written papers in mathematics and statistics,

(ii) one three-hour written paper in design of computer equipment, electronics and analogue computing,

(iii) one three-hour written paper in electronic data processing, accounting and industrial management, and

(iv) one three-hour written paper in programming theory and a qualifying essay arising from studies in the humanities.

Part Two—

- (i) Three three-hour written papers in information transmission, complete systems and the theory of automata and systems programming, and one three-hour written paper in the chosen special subject,
- (ii) an assessment of the report on the special project, including an oral discussion of it with the examiners, and
- (iii) a qualifying essay arising from studies in the humanities.

C. *John Dalton College of Technology, Manchester: Higher National Diploma in Mathematics, Statistics and Computing*

Entrance Requirements: Normally applicants should be at least 18 years of age and should have either

- (*a*) passed mathematics at General Certificate of Education Advanced level and have studied another suitable subject to Advanced level or passed physics at General Certificate of Education Advanced level and have studied mathematics to Advanced level, or
- (*b*) passed Ordinary National Certificate or Ordinary National Diploma in science with 50 per cent marks in each final paper.

Syllabus

All students study the following subjects:

Mathematics, physics, numerical analysis, computer programming, computational methods, and statistics.

Students have the option of studying either:

- (*a*) the circuiting of computers leading to a career in computer design, i.e. additional physics, computer electronics and analogue computing; or
- (*b*) the applications of computers in industry leading to a career in industry or commerce, i.e. operational research, accountancy and ergonomics.

Additionally all students will carry out a project in their third year in an optional subject.

Appendix 6
(paragraph 89)

UNIVERSITY POST-GRADUATE COURSES WITH SUBSTANTIAL COMPUTER ELEMENT

University or College	*Student numbers*			
	1964	1965	Optimum	Maximum
(*a*) COMPUTING SCIENCE (1)				
Leeds University	7	8	8	10
London: Birkbeck College (2)	30	18	15	25–30
Imperial College (3)	—	—	15	20
Institute of Computer Science (4)	5	6	7	10
Manchester University Institute of Science and Technology (5) (6)	—	3	10	18
Edinburgh University	6	4	12	20
Glasgow University	4	3	10	12–15
Belfast: Queen's University (3)	—	—	Not yet	available
Total (*a*)	52	42	77	115–123
(*b*) NUMERICAL ANALYSIS AND COMPUTING (1)				
Cambridge University	17	12	25	30
Liverpool University	6	6	12	15
London: Institute of Computer Science (4)	1	1	7	10
Newcastle upon Tyne University	13	12	15	20
Southampton University	6	8	15–20	30
St. Andrews: Queen's College, Dundee	1	6	8	12
Belfast: Queen's University	10	15	20	40–50
Total (*b*)	54	60	102–107	157–167
(*c*) HUMAN SCIENCES — OPERATIONAL RESEARCH, ETC. (1)				
Birmingham University	11	15	18	22
London: Imperial College	17	23	24	40
London School of Economics	1	18	12	20
Woolwich Polytechnic (5)	—	4	15	20
Newcastle upon Tyne University	1	3	10	15
Total (*c*)	30	63	79	117
Total (*a*)–(*c*)	136	165	258–263	389–407

NOTES:

(1) These courses are given under the classification adopted by the Science Research Council. In practice, we understand that there is considerable overlap in the nature of the courses concerned.

(2) 30 students on a two-year part-time diploma course reduced through wastage to 18 in second year. In 1966 the course was replaced by a one-year full-time M.Sc. course.

(3) Courses started in October 1966.

(4) These figures exclude some part-time and extra-mural students from industry, Government departments and other colleges of London University who attend sections of the lecture course.

(5) Courses started in October 1965.

(6) Additionally Manchester University operate a Research School in Computing Science which had eight students in 1965.

Printed in England for Her Majesty's Stationery Office by McCorquodale, London

M1368 Dd. 129522 K40. 1/67 3309.

DEPARTMENT OF EDUCATION AND SCIENCE
SCOTTISH EDUCATION DEPARTMENT
MINISTRY OF EDUCATION FOR NORTHERN IRELAND

Computer Education

Report of an Interdepartmental Working Group

LONDON
HER MAJESTY'S STATIONERY OFFICE
1967

FOREWORD

In October 1965, in view of the rapid prospective increase in the use of computers throughout the United Kingdom, an Interdepartmental Working Group was set up to consider what implications this might have for the educational system.

Their report identifies certain crucial needs in computer education and indicates how they can be met. Some of the initial steps have already been taken. But this report emphasises that if the provision of trained computer manpower is to keep pace with the growing requirements, both education and industry will need to take a fresh look at what is being done and co-operate even more closely over their education and training activities in this field. We strongly urge all those concerned to make a concerted drive on the lines suggested in this report and so help to meet the critical needs of the years immediately ahead.

ANTHONY CROSLAND
Secretary of State for Education and Science

WILLIAM ROSS
Secretary of State for Scotland

W. J. LONG
Minlster of Education for Northern Ireland

December, 1966

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